WEATHER

and

Weather Instruments

for the Amateur

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FIFTH AND REVISED EDITION

COMPRISING

PRACTICAL HINTS FOR AMATEUR WEATHER FORECASTERS
THE BAROMETER AS THE FOOTRULE OF THE AIR
THE THERMOMETER AND ITS FAMILY TREE
HUMIDITY ITS EFFECT ON OUR HEALTH AND COMFORT
THE MOUNTAINS OF CLOUDLAND AND RAINFALL
THE COMPASS THE SIGN-POST OF THE WORLD

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"Everywhere, skin deep below our boasted science, we are brought up short by mystery impalpable, and by adamantine gates of transcendental forces and incomprehensible laws, of which the Lord, who is both God and Man, alone holds the key, and alone can break the seal."

Chas. Kingsley

PRACTICAL HINTS FOR AMATEUR WEATHER FORECASTERS

THESE brochures are written with the idea of simplifying the readings of weather instruments to the mind of the layman and are arranged to help him in the forecasting of weather.

Weather, since it governs our health, habits, and pleasure, is a topic of such universal interest that it is no wonder the public is following the subject more closely.

Whilst it is impossible to accurately lay down laws in regard to coming weather, and the effect of winds upon it, a good general idea can be gained by the intelligent perusal of these pages.

"Weather" is different in different localities. Observers should cultivate the habit of carefully noting weather changes in their locality, especially the sequences in which these changes occur, for it is only by this method that these forecasts can be used to the best advantage.

No hard and fast rule can be laid down, for the details vary considerably. Each one must use his own judgment, based on his knowledge of his own particular locality.

See that all instruments used in connection with observations are of good or standard grade. Nothing is so disheartening to one following this interesting subject as instruments which at times give reason for doubting their accuracy.

Develop patience and persistency in following your work. John Ruskin, when a boy at Oxford University, in writing an essay on Meteorology, said:

"One following this science will find himself part of one Mighty Mind—a ray of light entering into one vast eye—a member of a multitudinous Power, contributing to the knowledge and aiding the efforts which will be capable of solving the most deeply hidden problems of nature, penetrating into the most occult causes, and reducing to principle and order the vast multitude of beautiful and wonderful phenomena, by which the wisdom and benevolence of the Supreme Deity regulates the course of the times and the seasons, robes the globe with verdure and fruitfulness, and adapts it to minister to the wants and contribute to the felicity of the innumerable tribes of animated existence."

HINTS TO OBSERVERS

An important fact, too often overlooked, is that the aneroid foretells, rather than indicates, weather that is present. The aneroid barometer generally indicates changes in weather 12 to 24 hours in advance.

It is essential that a comparison of the barometer readings for several days be taken into consideration before a good forecast can be made. It is for this reason that the recording barometer (Stormograph) is preferable to those of ordinary registering type.

Do not hang the barometer outside. It will work better inside, but in order to get the best results it should be kept in as equal a temperature as possible, provided it is not "Compensated for temperature." When compensated, temperature changes will have no effect on it.

Under no conditions put faith in the weather words, when they appear on the dial. They are approximate only, and if the hand points to "Rain" it does not follow that that condition must exist.

The figures "31," "30," "29," "28," etc., represent inches of pressure. Between the inches, dials are divided into lesser quantities, sometimes 1/10th of an inch (0.10), sometimes 1/20th of an inch (0.05), sometimes to 1/50th of an inch (0.02), and sometimes to 1/100th of an inch (0.01). It is usual to represent the tenths by longer dividing lines and to figure them. Study your dial carefully before attempting to register readings from it.

See that your barometer is corrected to a "sea level" reading before comparing it with any forecast.

If after purchase you find it is not "corrected" refer to page 11 and carefully follow the instructions.

Take care that you take a record of the reading of the barometer before you remove the blue hand.

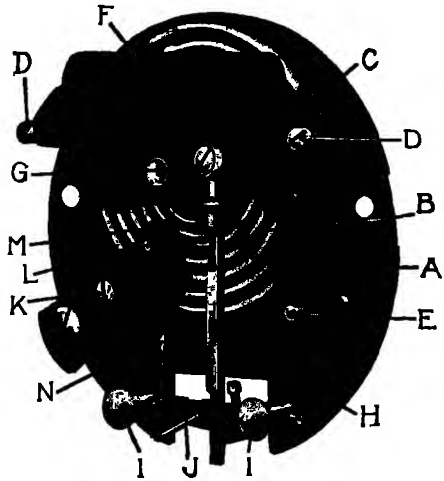
Example: Barometer uncorrected reads 28.20 inches, altitude 1,750 feet. Remove the hand. Correction for 1,750 feet is 1.93 inches; add this to 28.20 and the result, 30.13 inches, is the point at which the hand should be refitted. Make final fine adjustment by means of small screw in back. Do not attempt to move the hand more than three-tenths of an inch by means of this screw.

Take care that you make a record of the reading of the barometer before you remove the blue hand.

Press the hand carefully but firmly upon the central pin, to make sure it will not become loose under the strain of the continual tapping to which many people subject their barometers.

The trouble of adjusting a barometer for any particular altitude can be eliminated by using the instrument described under "A Self Adjusting Barometer."

THE ANEROID BAROMETER
(Construction)



A. Metals, or base plate, upon which parts are set.

B. Corrugated Chamber of nickel-silver (metal thickness 0.004 inches), from which all air is exhausted. It is secured to the plate "A" by a screw which passes through the plate and to which a nut is fastened.

C. Bridge which spans vacuum chamber "B."

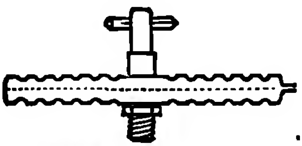
D.D. Adjusting screws which are used to either raise or lower the bridge, thereby altering the tension on chamber "B."

E. Adjusting screw which raises bridge "C" either up or down. The head of this screw is seen in the back of all aneroids.

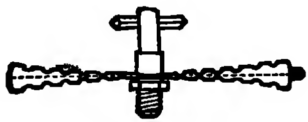
F. Steel spring, which is held in a slot in bridge "C."

G. Knife-edge (triangular or square steel rod). This passes through the stud of the vacuum chamber and rests on the spring so that the pull of the spring is transferred to the stud and tends to open the vacuum chamber.

At this point it is interesting to note that the mechanism is already sensitive to changes in atmospheric pressure. As the vacuum chamber is similar to a small circular metal box (closely resembling two lids of a tin can soldered together at their edges), it will, when exhausted of air, collapse. If we pull it from the bottom and also from the top we pull it open, but directly we let go it collapses again.



Before Exhausting Air



After Exhausting Air

As the under side is secured to the base plate "A" and the upper side is secured to the strong spring "F," the action is the same as the illustration just given, of the two tin can lids, viz., the strong spring "opens" the vacuum chamber and holds it open. If now we increase the pressure or weight on the vacuum chamber it pulls the spring down with it; if we decrease the pressure the spring opens it up more than ever.

It is now easy to see that this spring moves up or down as the air pressure decreases or increases. If we secure an arm to it, we will magnify its movement at the end of the arm.

H. Bar, or arm, compensated for temperature, which at its end magnifies movement of the spring "F."

I.I. Two supports or pillars fitted to plate "A."

J. Bar or regulator, set between and working on steel points or pivots passing through supports "I.I."

If the illustration be carefully studied it will be noticed that there is a small rod passing from the end of the bar or arm "H" to the edge of the bar or regu-

lator "J." If now the arm "H" moves in a downward direction it will tend to move the bar or regulator "J" in an outward direction, and if the arm is elevated, the bar or regulator will turn inward toward the vacuum chamber. An arm is set in an upward direction from the regulator "J," which at its upper end greatly magnifies the movement.

K. Arm or cock.

L. Pin or arbor passing through end of cock "K."

M. Hairspring, fitted to pin "L."

N. Chain of steel, one end of which is fitted to arm passing upward from regulator "J," the other being secured to pin "L," to which the indicating hand is fitted.

HOW TO READ BAROMETERS

The illustration shows a registering barometer of a type mostly in use.

The indicating hand is the darkened hand, responding readily to any change in atmospheric pressure, which ordinarily brings with it a change in existing weather conditions.

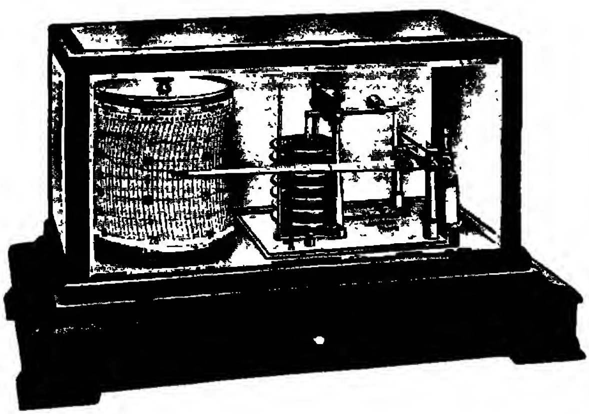
The lighter hand is the hand, "set" and is actuated by means of a brass knob, which passes through the glass.

It is intended that this "set" hand should be placed over the dark hand, which is done by rotating the knob in the glass.

On second observation it is possible to trace any change in the position of the barometer. This will be shown by the blue, or indicating, hand being either to the right or the left of the "set" hand, dependent on the change in atmospheric pressure.

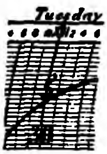
The illustration shows barometer reading at 29.33 inches, while the set hand is reading at 28.78 inches.

The Stormograph, or self-recording barometer, gives a continuous record of weather conditions, tracing them by means of a pen on a chart which is wound around a rotating clock drum. These charts are divided into the days of the week and sub-divided into two-hour spaces, so that the behaviour of the barome-



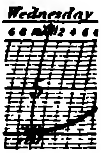
ter for any preceding time is noted, all changes being faithfully recorded. With the ordinary, or registering, barometer quick changes are apt to occur, which are not noted by the observer. These quick changes mean passing storms, and are all registered ahead on the Stormograph.

By consulting the record it is quite easy to see whether the change has been gradual or rapid and the instrument is to be greatly preferred in all respects to those of the ordinary registering variety.



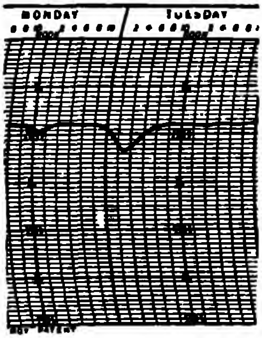
Convex

With a rising record the trace of the pen is convex for a decreasing rate and concave for an increasing one. The reverse is true of a falling barometer. If the fall or rise is steady the line will be straight diagonally.



Concave

This cut illustrates one advantage of the Stormograph. Two observations of an aneroid were made (at 10 p. m. and 8 a. m., respectively), both showing a reading of 30.10 in., which would indicate a "stationary" barometer with a continuance of present weather. A glance at the barograph record shows a rapid fall and rise between 10 p. m. and 8 a. m., which indicates a short but severe storm.



Speaking of a certain "delicate" barogram, Hon. Ralph Abercromby, F. R. Met. Soc., London, says:

"A case of this sort shows, more than any other, the superior value of a continuous trace over an intermittent barograph, for though the latter permits the tabulation of hourly values, they entirely lose all chance of following these minute alterations of pressure which are often accompanied by great changes of weather."

Stormographs are invaluable for mariners, as they are not affected by the roll and motion of a vessel at sea. Here it is important to know not only the amount of rise or fall, but also whether rapid or slow, as winds and seas depend upon these conditions. In all well appointed vessels it is now recognized as a necessity.

The following illustration shows a greatly magnified reading of barometer changes. The instrument from which the record was taken is known as a Micro-Barograph and is constructed on the same general lines as the Stormograph, but is much more sensitive to weather changes, and its record as a consequence is greatly magnified.

Minute fluctuations are discernible by this instrument which in the ordinary way are lost on account of the smallness of the change.

SEA LEVEL AND WHAT IT IS

The air at sea level (weighted down by the air above it) exerts a pressure of about 14.7 pounds per square inch of surface. The pressure on a grown person (average 16 square feet) would be about 35,000 pounds. Were it not for the ease with which the air (under this pressure) penetrates the body, very slight changes in pressure would prove disastrous.

Like terrestrial solids and fluids, the atmosphere is held in place by the attraction of the earth. As the area of the earth's surface is one hundred and ninety-seven million square miles, or seven hundred and ninety quadrillion inches, the total weight of the atmosphere is eleven and two-thirds quintillion pounds.

Some idea may be obtained of the enormity of these values by instituting a few interesting comparisons. One million trains each composed of one million powerful locomotives would represent but the hundredth part of the weight of the atmosphere. A leaden ball equal in weight to the atmosphere would have a diameter of 60 miles.

This law (decrease of pressure) being known, its principle is used in measuring the height of hills and mountains by means of barometric observations at the two points.

"Sea level," as applied to weather matters, means the reading of the barometer at an altitude corrected in such a manner that it would give a reading equal to the reading of the barometer if the place of observation were at sea level, instead of at an elevation. The higher we go the less the pressure of air. Refer to the illustration on page 16 and imagine that the pressure all over the section illustrated is relatively equal, so that at "A", the level of the sea, there is a pressure of 30 inches. At Station "B" (Cobourg, Ill.), it is 28.92 inches.

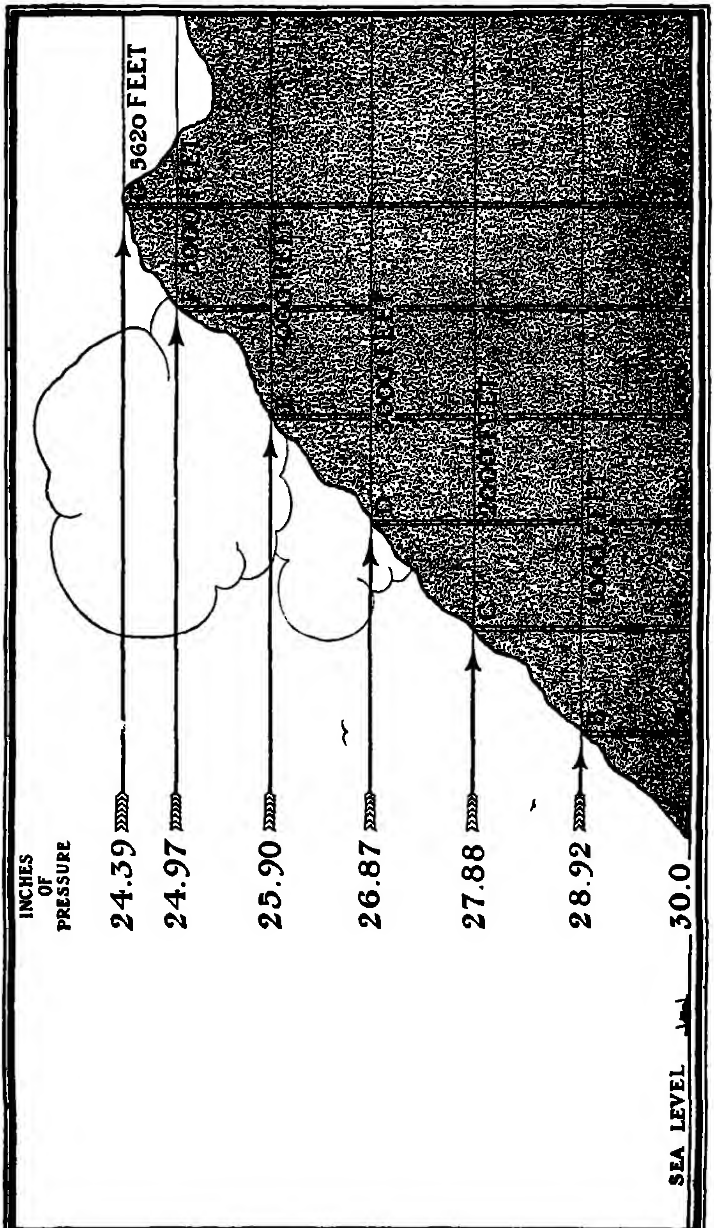
At "C" (Lowell, Neb.) the pressure is 27.88 inches, at "D" (Spica, Kansas), 26.87 inches, at "E" (Kanorado, Kansas) 25.90 inches and at station "F" (Canfield, Colo.) it is 24.97 inches. The altitude of these stations is noted by the descriptive letter in the illustration. If at these points the townspeople were to dig deep holes until they reached a point equal to "sea level" and took their barometers down, they would all read 30.0 inches.

The pressure at sea level is not stationary. It has read as high as 31.7 inches, and as low as 26.96 inches, but both these readings are extreme. The barometer at sea level on the average moves only between 28.40 for a low point to 30.30 for a high point. If the pressure at sea level varies a tenth of an inch, all places above it under similar conditions vary in a like ratio.

Consequently some standard of level had to be selected, so that barometers could be "set," or "corrected," for some predetermined point.

This is easy to understand when one considers the Weather Service Bureaus, scattered as they are over the United States and at different elevations.

Let us take, for example, the illustrations. The Bureau barometer at Station "A" would read 30.0, and at Station "B" 28.92, at Station "C" 27.88, and so on. Readings are taken at a certain time in the day at every Bureau in the country and telegraphed to the main office in Washington, D. C. If "A" telegraphed "30," "B" "28.92," "C" "27.88," "D" "26.87," and so on, the Chief Forecaster at Washington would receive no value from the information, unless he determined the elevation of each individual station and made the necessary correction to bring it to a "sea level reading." Consequently each reading is "reduced to sea level" before being issued, and instead of telegraphing in "30," "28.92," "27.88," etc., they would


INCHES OF PRESSURE
24.39
24.97
25.90
26.87
27.88
28.92
30.0
SEA LEVEL
5620 FEET

send in "30," "30," "30," etc., being the point at which the barometer would stand were it to be taken straight down in a vertical line to the level of the sea.

We may have seen the "weather map," and noted the lines called "isobars" that represent the barometer readings marked 30.2, 30.1, 30.0, 29.9, etc., existing over different sections of the country.

Every town touched by one of those lines has a pressure equal to that noted at the end of the line, when REDUCED TO SEA LEVEL. By this means pressures of equal value can be traced, and it is easy to see which section has a "low" barometer and which section has a "high" barometer reading.

Terms Used in Forecasting.

"Fair Weather"—that is, the absence of rain or snow, may be indicated by one of several terms. The words themselves may be used, or they may be employed singly or preceded by the word "generally." "Generally fair," as used in the forecast, is less positive than "fair' alone. It signifies that the probability of fair weather over the whole district and for the entire period is not so great as when "fair" alone is used.

Partly Cloudy—Rain—Snow.

"Partly cloudy" is used when the indications favor clouds but no precipitation (rain or snow). "Threatening" means the weather will be overcast and gloomy, with the appearance of rain or snow at any moment, yet a measurable amount of precipitation is not anticipated.

A forecast of "rain" or "snow" may be expressed in various ways. In the late fall, early spring and the winter season it is most commonly indicated by the single word "rain" or "snow," when it is expected that the rain will continue for several hours. In other seasons of the year any one of the following terms, such as: "local rain," "showers," and "thunderstorms," may be used.

Forecasts of local rains, showers or thunderstorms indicate that the conditions are favorable for the occurrence of precipitation in that district.

Clearing.

"Clearing" is a word frequently used which carries a broader meaning than the word itself signifies, viz.: the occurrence of precipitation in the early part of the period; thus, "Clearing tonight" would indicate that rain or snow, whichever might be falling at the beginning of the period, would cease shortly thereafter and that the weather would be clear during the greater part of the time.

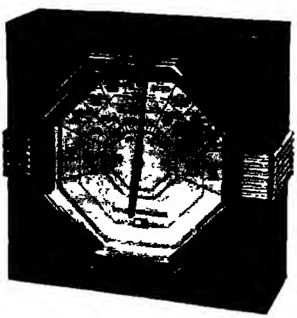
THE STORMOGUIDE
A SEMI-AUTOMATIC WEATHER INDICATOR

Most people when providing themselves with a weather barometer, put too much faith in the weather words which appear on the dial. These weather terms are simply relative and are more for decorative than practical purposes. They were placed on the original barometers and the practice has been continued.

Many devices have been constructed to use with barometers to enable the observer to obtain some idea of coming weather, but by far the most practical is the "Stormoguide," an instrument constructed along the same general lines as the barometer, but with its dial arranged and worded so that most practical weather forecasts can be immediately obtained.

In use it is simplicity itself and all the troubles usually caused by altitude changes are taken care of in the "self adjusting for altitude" feature, so it naturally becomes the most sensible and practical weather prognosticator for amateurs.

The forecasts are arranged for both "Falling" and "Rising" readings. The indicating hand travels around the dial as on all other barometers, but the barometer or "inch" scale has sectors extended from it in which these forecasts appear.



FAIRFAX STORMOGUIDE

This instrument has the Taylor Automatic Signal, showing at a glance whether the barometer is rising or falling, and making a "Setting" hand unnecessary.

As an example, the section 29.30 inches to 29.60 inches has two forecasts. A movement of the hand to the right indicates a rise between these pressures and the forecast is "High Winds with cool wave preceded by Squalls." If the movement of the hand is to the left, the falling forecast applies which is "Clearing, slight squalls, fair and cooler tomorrow." Naturally if the temperature outside be below the freezing point, "Rain" would have to be understood as "Snow".

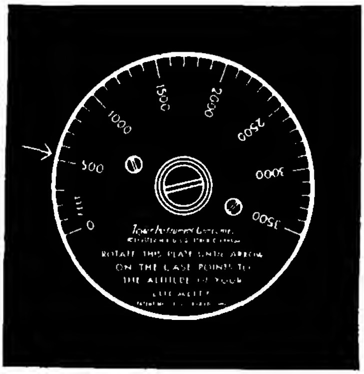
A SELF-ADJUSTING BAROMETER
FOR GENERAL USE

A good barometer for use above sea level is the "Stormoguide" illustrated above.

This instrument "automatically" sets itself to the correct reading, if the plate on the back of the case is turned with the fingers until the arrow which is engraved on the case points to the altitude of the location at which the barometer is being used.

The setting is extremely simple and can be accomplished in a few seconds. Once adjusted, no other change is necessary until the barometer is used in another location.

Instruments of this type are available for all points above sea level and below 3500 feet, and others for altitudes between 3500 and 7000 feet.



Back View of the Taylor Stormoguide

Practically a universal pattern as regards its adaptability to altitude, this instrument is a most interesting and useful barometer, for it can be taken on vacations, used while traveling or at home, and at all times can be correctly adjusted for its location.

It is made with either a good grade or a high grade compensated movement and the improved mechanism offers an ideal arrangement for all purposes.

NEVER make this altitude change by means of the small screw seen in the back of the instrument. For method of setting a barometer without the self adjusting feature see page 7 and below.

HOW TO "SET" BAROMETERS

Applicable only to those barometers which are not provided with an altitude setting dial on the back.

If the observer is situated at any point above sea level, the barometer, unless corrected, will read lower than the reading at sea level, on account of the lessened pressure due to altitude.

After finding the altitude and determining the difference, the indicating hand of the barometer should be

lifted off the pin onto which it is fitted and replaced at the corrected reading.

CORRECTIONS FOR ELEVATIONS ABOVE SEA LEVEL

If	altitude	is	250	feet	add	0.29	inches	to	barometer	reading
"	"	"	500	"	"	0.57	"	"	"	"
"	"	"	750	"	"	0.85	"	"	"	"
"	"	"	1000	"	"	1.12	"	"	"	"
"	"	"	1250	"	"	1.39	"	"	"	"
"	"	"	1500	"	"	1.66	"	"	"	"
"	"	"	1750	"	"	1.93	"	"	"	"
"	"	"	2000	"	"	2.20	"	"	"	"
"	"	"	2500	"	"	2.72	"	"	"	"
"	"	"	3000	"	"	3.24	"	"	"	"
"	"	"	3500	"	"	3.74	"	"	"	"
"	"	"	4000	"	"	4.24	"	"	"	"
"	"	"	4500	"	"	4.72	"	"	"	"
"	"	"	5000	"	"	5.20	"	"	"	"
"	"	"	5500	"	"	5.67	"	"	"	"
"	"	"	6000	"	"	6.13	"	"	"	"
"	"	"	6500	"	"	6.58	"	"	"	"
"	"	"	7000	"	"	7.03	"	"	"	"

For instance, suppose the observer be at an altitude of 500 feet and the barometer reads 29.20 inches. If the station were at sea level instead of being 500 feet above (or straight down 500 feet in a vertical line), the barometer would read 0.57 inches higher, so the corrected reading would be 29.20, plus 0.57=29.77 inches.

MERCURIAL BAROMETERS

Mecurial barometers are read in a similar manner to those of aneroid type. The scales are divided into inches of pressure and subdivided into tenths or twentieths of an inch. A vernier is usually attached, so that even closer readings can be made.

The theory of the instrument is exactly the same as that used by Torricelli, its inventor, in 1643. If a glass tube, closed at one end, 34 to 36 inches long, is

filled with mercury and inverted into a cup of mercury, the mercury in the tube will fall in the tube to a height

(at sea level) of approximately 30 inches, irrespective of the length of the glass tube. The height is measured in inches from the level of the mercury in the cup to the level of the mercury in the tube.

The weight of the air on the mercury in the cup holds the mercury at a certain height in the tube. When the pressure is released, the mercury in the tube will naturally fall, but will rise when the pressure is increased.

As mercury expands or contracts when the temperature increases or decreases, corrections to the mercury column are necessary before a true reading of atmospheric pressure can be arrived at. Standard temperature is 32° Faht. or 0° Centigrade.

Another necessary correction is an adjustment of the cistern. In a modern mercury barometer a "cup" is not used, as described above. Instead the mercury is placed in a cylinder of glass, the barometer tube passing through a neck into it.

There is a small ivory point inside the top of this glass cylinder and before a reading can be taken the mercury has to be raised or lowered in the cylinder (by means of an adjustment underneath), until its exact level just touches the ivory point. If this is not done carefully and accurately the readings will be erroneous.

A small correction for gravity is necessary, which must be taken into consideration, and also one for meniscus. Mercury will not wet glass, but as capillary attraction depresses the column and gives it a rounded top, it is necessary to

determine what the reading would be if the mercury column were cut straight across instead of being rounded. This is called "meniscus correction."

The metal scales, upon which are engraved the inches of pressure, are affected by temperature, being longer when warm and shorter when cool. A correction has also to be applied here.

When all these corrections have been found and applied to the reading of the barometer, a true reading of the atmosphere is possible.

In high-grade COMPENSATED aneroid barometers, all corrections are taken care of in construction, and the observed reading on the dial is the true reading.

EFFECT OF TEMPERATURE ON THE WEATHER

Barometer Rising

Below 30° Faht. . . . . Cold Wave.
Between 30° and 40° Faht. . . . Freezing.
Between 40° and 50° Faht. . . . Probable Frost.
Between 50° and 60° Faht. . . . Cooler.
Above 60° Faht. . . . . Warm with cool nights.

Barometer Falling

Below 30° Faht. . . . . Snow Storm.
Between 30° and 40° Faht. . . . Rain or Snow.
Between 40° and 50° Faht. . . . Rain Storm.
Between 50° and 60° Faht. . . . Heavy Rains.
Above 60° Faht. . . . . Showers.

The above are OUTSIDE temperatures, and should be taken in the shade with a thermometer of known accuracy, exposed in such a manner as to have a perfect circulation of air around its bulb.

BEAUFORT'S SCALE OF WINDS

Used Mostly at Sea

		Statute Miles Per Hour
0	Calm	0 to 3
1	Light air	3 to 8
2	Light breeze	8 to 13
3	Gentle breeze	13 to 18
4	Moderate breeze	18 to 23
5	Fresh breeze	23 to 28
6	Strong breeze	28 to 34
7	Moderate gale	34 to 40
8	Fresh gale	40 to 48
9	Strong gale	48 to 56
10	Whole gale	56 to 65
11	Storm	65 to 75
12	Hurricane	75 and over

SCALE OF WINDS

As Used by British Meteorological Office

Beaufort	Miles Per Hour	Meters Per Second	Feet Per Second	Pressure Pounds Per Square Foot
No.	Less than	Less than	Less than	
0	1	0.3	2	0.00
1	1–3	0.3– 1.5	2–5	0.01
2	4–7	1.6– 3.3	6–11	0.08
3	8–12	3.4– 5.4	12–18	0.28
4	13–18	5.5– 8.0	19–27	0.67
5	19–24	8.1–10.7	28–36	1.31
6	25–31	10.8–13.8	37–46	2.3
7	32–38	13.9–17.1	47–56	3.6
8	39–46	17.2–20.7	57–68	5.4
9	47–54	20.8–24.4	69–80	7.7
10	55–63	24.5–28.4	81–93	10.5
11	64–75	28.5–33.5	94–110	14.0
12	Above 75	33.6 or above	Above 110	17.0 or over

WINDS

> " When the glass falls low,
> Prepare for a blow;
> When it rises high,
> Let all your kites fly."

In the Northern Hemisphere, standing with your face to the wind, the barometer will be lower on your right hand than on the left. The reverse of this is true for the Southern Hemisphere.

Wind will be, or may be expected to be:—
Easterly when the pressure is high in N. or low in S.;
Southerly when pressure is high in E. and low in W.;
Westerly when pressure is high in S. or low in N.;
Northerly when pressure is high in W. or low in E.

A rapid rise or a rapid fall intimates that a strong wind is about to blow, and that the wind will bring with it a change in the weather. What the precise nature of the change is to be must, ordinarily, depend upon the direction from which the wind blows.

"Veering" wind is a wind that moves from left to right; i.e., " clockwise."

If the wind shifts the opposite way, the change is called " backing," indicating the approach of another storm.

> " When the wind veers against the sun,
> Trust it not, for back 'twill run."

GENERAL INDICATIONS

Barometer Rising

1. A gradual but steady rise indicates settled fair weather.
2. A very slow rise from a low point is usually associated with high winds and dry weather.
3. A rapid rise indicates clear weather and high winds.

The barometer rises for northerly wind (including from northwest, by NORTH, to Eastward), for dry or less wet weather, for less wind, or more than one of these changes—except on a few occasions when rain, hail, or snow, comes from the northward with STRONG wind.

GENERAL INDICATIONS

Barometer Falling

4. A gradual but steady fall indicates unsettled or wet weather.
5. A very slow fall from a high point is usually connected with wet and unpleasant weather, without much wind.
6. A sudden fall indicates a sudden shower, or high winds, or both.

The barometer falls for southerly wind (including from southeast by the SOUTH to the westward), for wet weather, for stronger wind, or for more than one of these changes—except on few occasions when MODERATE wind with rain (or snow) comes from the northward.

APPROXIMATE BAROMETER READINGS

Barometer Rising

29.0 to 29.3 inches. . Clearing, with high winds and cool wave.

29.3 to 29.6 inches. . High winds, with cool wave, preceded by squalls.

29.6 to 29.9 inches. . Fair weather, with fresh winds tonight and tomorrow.

29.9 to 30.2 inches. . Fair, with brisk winds, which will diminish.

30.2 to 30.5 inches. . Generally fair weather, probably cool today, with variable winds.

30.5 to 30.8 inches. . Clear weather tonight and continued cool, with moderate winds.

30.8 to 31.0 inches. . Southeast rains with high winds.

APPROXIMATE BAROMETER READINGS

Barometer Falling

30.7 to 30.5 inches. . Fair and warmer, followed by wind and rain.

30.5 to 30.2 inches. . Storm brewing in the direction of the wind.

30.2 to 29.9 inches. . Cloudy and warmer, followed by unsettled weather.

29.9 to 29.6 inches. . Unsettled weather, increasing winds and warmer.

29.6 to 29.3 inches. . Clearing, slight squalls, fair and cooler tomorrow.

29.3 to 29.0 inches. . Clearing weather, with high winds, accompanied by squalls and cooler.

29.0 to 28.7 inches. . Stormy.

WINDS

Barometer Rising

S. to S.W. Barometer 30.0 inches, or below, and rising slowly.	Clearing within a few hours and continued fair for next few days.
S.W. to N.W. Barometer 30.10 to 30.20 inches, steady.	Fair, with slight temperature changes.
S.W. to N.W. Barometer 30.10 to 30.20 inches, rising rapidly.	Fair, followed within 48 hours by warmer and rain.
Going to W. Barometer 29.80 inches, or below, and rising rapidly.	Clearing and colder.
Between N. and E. Barometer rising.	Weather turning cooler.
Between S.W. and S. Barometer rising.	Weather probably warmer tomorrow, but cloudy.

WINDS

Barometer Falling

S. to E. Barometer 29.8 inches and below and falling rapidly.	Severe storm of rain (in summer) or snow (in winter), imminent, clearing and colder in 24 hours.
S. to S.E. Barometer 30.1 to 30.2 inches, falling rapidly.	Rain in 18 to 24 hours.
S. to S.E. Barometer 30.1 to 30.2 inches, falling slowly.	Rain in about 24 hours.
E. to N.E. Barometer 30.10 and above and falling slowly (winter).	Rain or snow within 24 hours.
E. to N.E. Barometer 30.10 and above and falling slowly (summer).	With light winds; rain may not fall for several days.
E. to N.E. Barometer 30.10 inches and above and falling rapidly (summer).	Rain probable within 12 to 24 hours.
E. to N.E. Barometer 30.10 and above and falling rapidly (winter).	Rain or snow, with increasing wind, especially if wind is from N.E.
S.W. to N.W. Barometer above 30.2 inches and falling slowly.	Slowly rising temperature and fair for 48 hours.
S.W. to N.W. Barometer 30.1 to 30.2 inches and falling rapidly.	Warmer, with rain in from 18 to 24 hours.

Barometer Falling—(Continued)

S.W. to N.W. Barometer 30.1 to 30.2 inches and falling slowly.	Warmer, with rain in from 24 to 36 hours.
S.E. to N.E. 30 and below and falling rapidly.	Rain, with high winds, followed in 24 hours by clearing and cooler.
S.E. to N.E. 30 and below and falling slowly.	Rain for one or two days.
E. to N. Barometer 29.8 or below, falling rapidly.	Severe N.E. gales and heavy rains or snow, followed in winter by cold wave.
S.E. to S.W. With barometer falling.	Storm coming from W. or N.W., followed by cooler and W. to N.W. winds.
N. and E. With barometer falling.	Storm coming from S. or S.W., followed by cooler and N. to N.W. winds.

EXTREME READINGS OF THE BAROMETER

The following reports are of interest, since they give an idea of extreme readings taken in different parts of the world:

High Barometer Readings

Semipalatinsk, Siberia, December 16th, 1877—31.72 inches.

Fort Assiniboine, Montana, January 6th, 1886—31.21 inches.

Low Barometer Readings

Reikiavik, Greenland, February 4th, 1824—27.25 inches.

Cunard Steamer "Tarifa," Lat. 51° N., Long. 24° W., February 5th, 1870—27.33 inches.

False Bay, Bengal, September 22nd, 1885—27.13 inches.

Record Low Barometer Reading

"During the night of January 9-10th, 1913, remarkably low readings were recorded, the lowest, 26.96 inches, being registered by the aneroid barometer on the British Steamer "Manchester Inventor" at 1 a.m. the 10th, latitude 52° North, longitude 25° 30′ West. This is probably the lowest barometer reading ever made on the North Atlantic."

(From Royal Meteorological Society's Journal, July, 1913.)

THE BAROMETER AS THE FOOT RULE OF THE AIR

THE barometer, which only recently has come into popularity, was "invented" nearly three hundred years ago.

The work in connection with this invention is very interesting. It seems that Galileo Galilei, an Italian philosopher and mathematician (born 1564—died 1642), was asked toward the end of his life to explain why water could not be raised in a suction pump more than 32 feet.

He was led to believe that nature's abhorrence of a vacuum did not exceed the pressure of a column of water 32 feet high, but subsequently he devised an experiment to ascertain the power of a vacuum.

His apparatus, which was placed in an inverted position, consisted of a tube with a very smooth interior, into which a piston was closely fitted. Weights were applied to this piston to see how much pull was necessary to draw the piston down.

Previous to his death he recommended to his pupil (Evangelista Torricelli) that these experiments be continued.

His decisive experiment was in ascertaining the length of a column of mercury sustained by the same cause, whatever it might be, which supported the column of water.

As the weight of mercury is about fourteen times greater than that of water, he reasoned that the heights of the two should be proportional to their weights.

To prove his ideas on the subject, he took a glass tube about three feet in length, closed it at one end,

and filled it with mercury. Putting his finger on the open end he inverted this tube in a small bowl, also containing mercury, and when he removed his finger, found that the mercury sank down in the tube until its level in the tube was about 29 inches distant from the level of the mercury in the bowl.

Torricelli continued his experiments and found the level of the mercury in the tube fluctuated as changes in the weather took place. As early as 1645 he published his observations on this phenomenon.

He died at Florence, Italy, October 25, 1647, before his great discovery was fully completed.

At this time a French author, Blaise Pascal, became interested in Torricelli's discovery. His father had sent him to Paris for the study of languages, but the boy's mind ran along mathematical lines and by the time he reached the age of 12 he was reputed to be as far as the 32nd proposition of Euclid. His father on discovering this, decided to give him a mathematical education. He soon became associated with the scientific societies and astounded the most learned by his knowledge of mathematical problems.

At the age of 16 he had invented a calculating machine, although it was never put to practical use. He also had completed the first wheel-barrow chair, a type of dray, and the hydraulic press.

When 25 he started his barometrical experiments and confirmed the discoveries of Galileo, Torricelli, and others, regarding the weight of the air and its elasticity. It occurred to him that if the atmospheric pressure supported the mercury in the tube, as shown in Torricelli's experiment, the height of the column of mercury in the tube should increase or decrease if the pressure increased or decreased.

He took up his ideas with Périer, his brother-in-law, who lived near the high conical mountain of Puy-de-

Dôme, and requested that he should test his theory upon this mountain.

This was not accomplished until the autumn of 1648. Périer manufactured two tubes, filled them with mercury and observed them, leaving one in his garden at Clermont, the height of the mercury in the tubes being 26 French inches and 3¾ lines.

Leaving one behind to be observed during his absence, he took the other up the Puy-de-Dôme and at the summit observed that the mercury had fallen in the tube to 23 inches and 2 lines. Noting the tube as he returned he found at the lower levels of the mountain the mercury continued to rise until by the time he arrived in his garden at Clermont the mercury stood at its original level of 26 inches and 3¾ lines.

This was the first time observations had been made of air pressure in regard to elevations.

Pleased at his success and confident that the ideas of Pascal had been proven correct, he repeated the experiment, going to the highest tower in Clermont. He communicated the results of his experiments to Blaise Pascal, who himself made similar observations, both from a high house and a belfry in Paris.

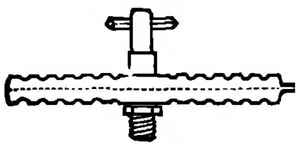
Satisfied beyond measure with the results, he proposed this process as a means for determining the heights of any one place above another. Thus the "barometer" was born and sent on its career throughout the civilized world.

The most distinguished men of science have worked to develop from this crude, but original instrument of three hundred years ago, the fine instrument of the present day, but the modern instrument is nothing but the original "tube inverted in a cup of mercury," with many refinements.

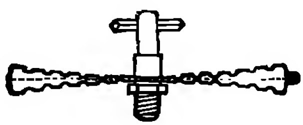
Patterns and styles have been many, the most ingenious and common pattern being the one operated by a mercury tube set in the back of a banjo-shaped

frame, to which is fitted a dial divided in inches, bearing the very familiar but grossly inaccurate legends "Stormy," "Fair," and "Fine Weather," over which an indicating hand travels.

In 1798 M. Comté, Professor of Aërostatics in the school at Meudon near Paris, invented a "watch-like, metallic, air-tight vacuum case, the lid of which, sustained by internal springs, rises and falls under variable pressures." This undoubtedly was the first "aneroid" (Greek compound "without fluid") barometer and was made for the reason that in his balloon ascents he found the mercury barometer suffered greatly from violent oscillation.



Barometer chamber before exhaustion



Barometer chamber after exhaustion

M. Vidi subsequently made a case of different form. He constructed a box with corrugations at the top and bottom to make it more elastic in its movements. When the air was withdrawn from this box it naturally collapsed at its centre. By a mechanical contrivance the two surfaces were made to open again by fitting studs to the upper and lower centre of each surface, pulling them apart, and mechanically holding them open. Any increase in the pressure of the air, of course, weighed down on this "box" or "chamber" and closed it slightly: any decrease in pressure had the opposite effect, and allowed it to open. This movement was transmitted to a series of levers terminating at a small post or pin to which an indicating hand was fitted. A

suitably engraved or figured dial enabled all changes in pressure to be fairly accurately and quickly read.

This, when completed, made a very portable instrument and at once sprung into popularity. It seems to have been further developed by English makers, and the result is that today there are made aneroid barometers constructed in such a manner as to show changes of as little as 1-1000th of an inch of pressure.

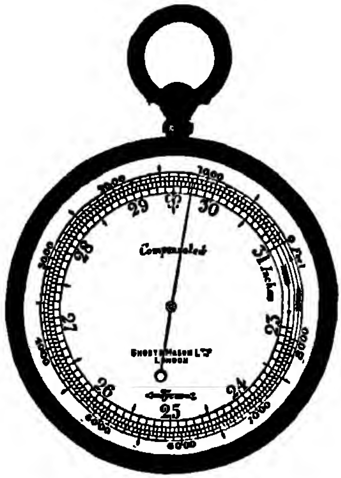
It has been the cause of much conjecture and a good deal of guessing on the part of many people how it is possible to know that a certain place is a certain number of feet above sea level. The writer once heard the remark, "They certainly cannot use tapes."

The invention of the aneroid type of instrument was of great importance since it would be out of the question to carry for any distance a large mercury barometer, at least 34 inches long, both cumbersome and unportable.

Made, as they are, in sizes varying from about two inches for the tourist or traveller up to five inches for the surveyor, they are not only very portable, but extremely accurate, providing they are not abused and are handled with ordinary care.

The finer instruments are sensitive to almost a hair line and consequently very fine and accurate readings can be taken, providing the aneroid is properly and carefully constructed.

The dials are divided into inches of mercury pressure and when we say the barometer is standing at "29" we mean that at that point of observation mercury would be supported at a height of 29 inches in a tube, as explained in the Torricellian experiment.



The pocket altitude barometer with unequally-divided altitude scale

Before dealing with the barometer as a measure of height it will be well to more thoroughly understand the air, the depth or height of which we attempt to measure.

The first thing to remember is, that since air is elastic, it is more compressed, and therefore weighs heavier at the surface of the earth than at any point above it.

The height of our atmosphere is not known. Nearly all authorities disagree on the subject.

Never being able to view it from the top we can never be able to solve this problem. We are imprisoned at the bottom of it.

The opinion has gained ground that this air ocean reaches to a height of certainly two or three hundred miles—possibly four or five hundred—possibly a good deal more.

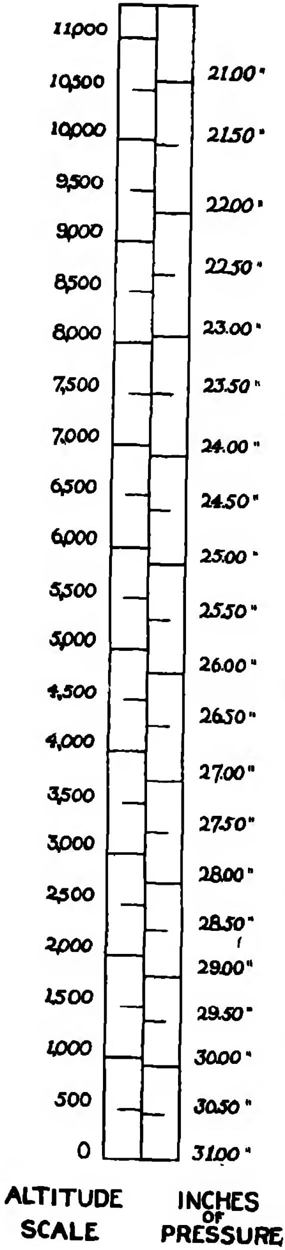
It is very difficult indeed to imagine the "top" of our atmosphere. The air shades off very gradually until it becomes the vacuum of space. This no living soul can explain, or even imagine. The thought of it is impossible. We, at the bottom of this great ocean of air, are as helpless in learning anything about the surface of it as is a flat fish at the bottom of the ocean of water in attempting to learn of its surface.

The atmosphere of the sun is said to extend for 500,000 miles—even this distance represents but a molecule of space, in the wonderful Universe.

How helpless we are. The average person knows very little about the air a mile or so above his head, or its condition. Even when at that height he must fight for breath should he exert himself to any extent.

These miles, maybe hundreds of miles of air, are pressing mightily downwards, packing tightly together the lower layers of air near the earth's surface. Here we live, right at the very bottom, and look on with wonder at the little mounds and heaps which we call mountains. True, they may be thousands of feet in height, but they are very small when compared to the depth of the air in which they are placed.

The upper layers of this air must be lighter or "looser" in their construction, for they do not have to support so much weight above. The greatest pressure is at the bottom. If we could cut the air up into slices of any size, each slice being equal to say half an inch of pressure, and pile them up thousands and thousands of feet into the air, the lower ones would be so squashed or compressed that they would not measure anywhere near the size of those above. Those toward the top would be nearer their original thickness and the very top one would be exactly the same size as it was before it was placed in position.



Perhaps this illustration can better be imagined if we use bales of cotton wool instead of blocks of air at a certain pressure. If the bales contained 100 pounds of cotton and were two feet thick, they would still contain 100 pounds of cotton if by the weight of the thousands above them they were compressed to a thickness of only one foot.

It is quite the same with the air. An inch of pressure at the level of the sea may be only 900 feet thick, but an inch of pressure, high up in the air, may be 1,500 feet thick.

By this simple illustration it is quite easy to see that the distances between each inch of pressure are not equal. A thousand feet of air is always a thousand feet of air, no matter if it is at a pressure of one inch or thirty inches. A foot rule is always the same length even though it be at the bottom of the sea, or on the summit of the highest mountain. The experiments of Blaise Pascal proved that if a barometer be taken up a mountain, hill or steeple, or to any place above a certain point, it will measure the difference in pressure between the first and last place of observation.

Working pressure in inches, into feet of measurement, was an

unhandy way of arriving at a result, and it remained for Sir George Biddell Airey, K. C. B., Astronomer Royal of Great Britain, to devise a scale of feet of measurement (see below) which exactly matched a scale of inches of pressure, to enable anyone to see the distance in feet they had traveled by subjecting their aneroid barometer to the pressure at a certain place and to that of one above it.

Aneroid or Corrected Barometer	Height in Feet	Aneroid or Corrected Barometer	Height in Feet	Aneroid or Corrected Barometer	Height in Feet	Aneroid or Corrected Barometer	Height in Feet	Aneroid or Corrected Barometer	Height in Feet
in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.
31.00	0	28.28	2500	25.80	5000	23.54	7500	21.47	10000
30.94	50	28.23	2550	25.75	5050	23.50	7550	21.44	10050
30.88	100	28.18	2600	25.71	5100	23.45	7600	21.40	10100
30.83	150	28.12	2650	25.66	5150	23.41	7650	21.36	10150
30.77	200	28.07	2700	25.61	5200	23.37	7700	21.32	10200
30.71	250	28.02	2750	25.56	5250	23.32	7750	21.28	10250
30.66	300	27.97	2800	25.52	5300	23.38	7800	21.24	10300
30.60	350	27.92	2850	25.47	5350	23.24	7850	21.20	10350
30.54	400	27.87	2900	25.42	5400	23.20	7900	21.16	10400
30.49	450	27.82	2950	25.38	5450	23.15	7950	21.12	10450
30.43	500	27.76	3000	25.33	5500	23.11	8000	21.08	10500
30.38	550	27.71	3050	25.28	5550	23.07	8050	21.05	10550
30.32	600	27.66	3100	25.24	5600	23.03	8100	21.01	10600
30.26	650	27.61	3150	25.19	5650	22.98	8150	20.97	10650
30.21	700	27.56	3200	25.15	5700	22.94	8200	20.93	10700
30.15	750	27.51	3250	25.10	5750	22.90	8250	20.89	10750
30.10	800	27.46	3300	25.05	5800	22.86	8300	20.85	10800
30.04	850	27.41	3350	25.01	5850	22.82	8350	20.82	10850
29.99	900	27.36	3400	24.96	5900	22.77	8400	20.78	10900
29.93	950	27.31	3450	24.92	5950	22.73	8450	20.74	10950
29.88	1000	27.26	3500	24.87	6000	22.69	8500	20.70	11000
29.82	1050	27.21	3550	24.82	6050	22.65	8550	20.66	11050
29.77	1100	27.16	3600	24.78	6100	22.61	8600	20.63	11100
29.71	1150	27.11	3650	24.73	6150	22.57	8650	20.59	11150
29.66	1200	27.06	3700	24.69	6200	22.52	8700	20.55	11200
29.61	1250	27.01	3750	24.64	6250	22.48	8750	20.51	11250
29.55	1300	26.96	3800	24.60	6300	22.44	8800	20.47	11300
29.50	1350	26.91	3850	24.55	6350	22.40	8850	20.44	11350
29.44	1400	26.86	3900	24.51	6400	22.36	8900	20.40	11400
29.39	1450	26.81	3950	24.46	6450	22.32	8950	20.36	11450
29.34	1500	26.76	4000	24.42	6500	22.28	9000	20.32	11500
29.28	1550	26.72	4050	24.37	6550	22.24	9050	20.29	11550
29.23	1600	26.67	4100	24.33	6600	22.20	9100	20.25	11600
29.17	1650	26.62	4150	24.28	6650	22.16	9150	20.21	11650
29.12	1700	26.57	4200	24.24	6700	22.11	9200	20.18	11700
29.07	1750	26.52	4250	24.20	6750	22.07	9250	20.14	11750
29.01	1800	26.47	4300	24.15	6800	22.03	9300	20.10	11800
28.96	1850	26.42	4350	24.11	6850	21.99	9350	20.07	11850
28.91	1900	26.37	4400	24.06	6900	21.95	9400	20.03	11900
28.86	1950	26.33	4450	24.02	6950	21.91	9450	19.99	11950
28.80	2000	26.28	4500	23.97	7000	21.87	9500	19.95	12000
28.75	2050	26.23	4550	23.93	7050	21.83	9550	19.241	13000
28.70	2100	26.18	4600	23.89	7100	21.79	9600	18.548	14000
28.64	2150	26.13	4650	23.84	7150	21.75	9650	17.880	15000
28.59	2200	26.09	4700	23.80	7200	21.71	9700	17.235	16000
28.54	2250	26.04	4750	23.76	7250	21.67	9750	16.615	17000
28.49	2300	25.99	4800	23.71	7300	21.63	9800	16.016	18000
28.43	2350	25.94	4850	23.67	7350	21.59	9850	15.439	19000
28.38	2400	25.89	4900	23.62	7400	21.55	9900	14.883	20000
28.33	2450	25.85	4950	23.58	7450	21.51	9950		

In March, 1867, he presented this scale to the "Royal Society of England," who passed upon it, and it seems to have been immediately adopted by English manufacturers, being in general use up to the present day.

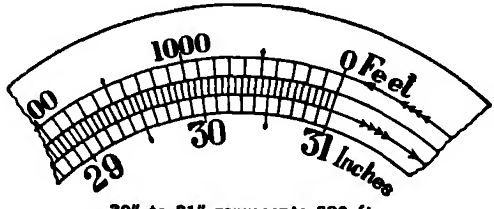
As a zero, or starting point, for the scale of feet had to be determined, he selected the thirty-one inch point, as the barometer at sea level never, or at least very rarely, indicated a pressure of air greater than this. Made in this way, he assumed that the hand of the barometer would always be at some point on the new scale of altitudes he had devised.

It is oftentimes wondered why the altitude zero was not started from thirty inches. The answer is quite simple, for if the barometer stood at some point higher than thirty inches (and it frequently does) the hand would be off the altitude scale and consequently no reading on it would be possible.

This scale had to be universal and had to be considered from the lowest point on land, which is sea level, since the height of any town, river or mountain is understood to be "so many feet above sea level."

Tourists are ofttimes greatly disappointed in viewing high mountains or peaks, to see them so apparently small.

When in Colorado, I well remember hearing a person at Pike's Peak for the first time exclaim, "Why, I was told this Peak was over 14,000 feet high!" He little thought that the Peak itself rises but 8,000 feet above Colorado Springs, and that Colorado Springs is 6,000 feet above sea level. He evidently expected to find a towering mountain rising 14,000 feet in the air, instead of 14,000 feet from the level of the sea.

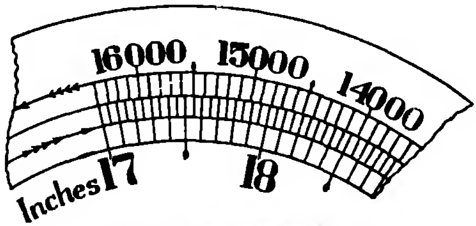


30" to 31" represents 890 ft.

In computing this scale it was found that the inch of pressure between "30" and "31" is 890 feet in thickness —small because

it is compressed by the very great weight of all above it. Between the inches "17" and "18" the distance was found to be 1,580 feet, much greater because of that height (approximately 14,000 feet) the air is much lighter, since it is not compressed by so much above.

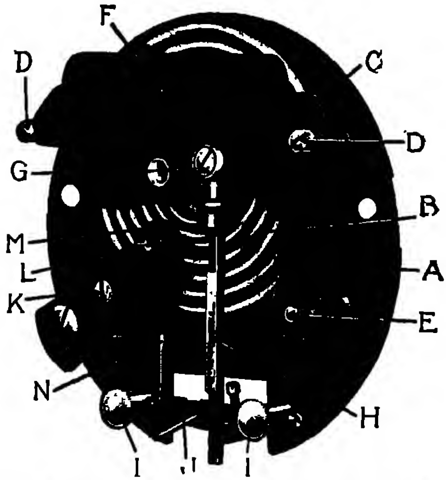
An altitude scale was thus devised and was accepted as correct at a temperature of 50° Fahrenheit. Mention of temperature in connection with this is made for the reason that air can be expanded or contracted by either increasing or decreasing its temperature. If the temperature is lowered, one inch of pressure shrinks a trifle in depth, and if the temperature be increased it becomes a trifle deeper. If we seal a tin and heat it, the air inside expands and breaks open the tin.



17" to 18" represents 1,580 ft.

The "altitude" and "inches of pressure" scales do not match one another; that is, they are not equal, and as they were originally computed with the 31-inch point as the zero, they become incorrect when used in any other manner, unless the altitude scale is manufactured in the new and improved way, viz., in equal divisions, which makes it correct when revolved to the point of the hand.

In manufacturing the mechanism for an aneroid barometer and arranging it to agree with the standard mercurial barometer, the natural order of things was usually reversed, that is, the pressure scale was divided in equal divisions, instead of being in unequal divisions as in nature, which, consequently, makes the altitude scale of divisions unequal, that really in nature are



Internal mechanism of modern altitude barometer

equal. In value they are exactly the same, that is, the unequal divisions of the one match the equal divisions of the other exactly, and are as correct as they would be if made and engraved according to nature. As noted in a previous paragraph, the new method is to make the altitude scale in equal divisions.

The old type of aneroid had its altitude scale sometimes engraved on the same plate as that on which the pressure or inch scale appeared. At other times these scales were made to revolve.

A revolving scale of this type is obviously incorrect and likely to be grossly misleading when in the hands of a novice, for it is quite natural for a person not thoroughly conversant with the instrument to turn the scale around until the "0" feet on the altitude scale is in a line with and directly under the point of the hand, before starting on a trip up a mountain or hill, naturally thinking one had to start from "zero" or "0" feet.

The result of this would be that the hand would start to move in that part of the altitude scale which

showed the widest division. As an instance, the value of the altitude scale between 28 inches and 27 inches is approximately 1000 feet, so if at the start of an observation the hand stood at 28 inches (represented on the altitude scale by 2750 feet) and at the termination of the climb at 27 inches (represented on the altitude scale by 3750 feet) the height between the two places would be the difference between the two readings; viz., 3750—2750=1000.

Now, if the scale be revolved until the "0" feet upon it stood directly beneath the hand at 28 inches, and the hand travelled during the ascension of the hill until it pointed to the 27-inch point, the altitude shown by the scale would be but 890 feet, or in error to the extent of 110 feet!

The cause of this, as explained before, is that the wrong part of the altitude scale was used in connection with a certain pressure.

The "0" feet of the altitude scale and the "31-inch" of pressure point must always be coincident if correct readings are desired on this type. There is no other way to use this barometer correctly.

With the new type of instrument the revolving altitude scale is divided in equal divisions and the "0" feet can be set at the hand, the ascent started and the altitude at any time read correctly off the dial, at the wish of the user. It is of great convenience and a marked advancement in instrument making.

It is popularly believed that an altitude barometer will give the observer information as to the height he is above sea level, by simply observing its dial. This it cannot do.

Altitude barometers simply indicate the height between one place of observation and another. They are practically rules, or measures, put up in a different form, but designed for the same purpose.

We realize the utter absurdity of endeavoring to find the altitude of a place at which we may be standing, by consulting a ruler. It is quite as absurd to expect to obtain this information by looking at the dial of an aneroid barometer.

The Geological Survey, U. S. Weather Bureau, U. S. Coast and Geodetic Survey, U. S. Geographic Survey, U. S. Engineer Corps, U. S. Lake Survey, U. S. Army, Geological Surveys of different States, Railroads, City Engineers, Clubs, and many individuals have established the elevation of different points above sea level over the whole country and their findings are on record in a volume of over a thousand pages.

Extra high-grade pocket altitude barometer with certificate of errors and equally-divided altitude scale

If it be necessary to find the elevation of a certain place above sea level, it is of course, necessary to start at, or near, one of these "bench marks," first noting its height above sea level and then determining by the aneroid barometer the difference in height between the "bench mark" and the second point of observation.

If, for instance, we were at Helena, Montana, we would find on the City Hall a mark "4108 feet above sea level." Supposing we wanted to find the difference

in elevation between Helena and Boulder, Montana, we would observe our barometer at Helena before starting. It might read at say 25.80 inches, equivalent to the 5000-feet mark on the altitude scale. On arriving at Boulder (Northern Pacific Railway), it would point to approximately 25.03 inches, equivalent to the 5815 feet on the altitude scale. The difference between the two readings is 5815 minus 5000 feet, or 815 feet.

Before starting we found the bench mark at Helena to be 4108 feet above sea level, so if we add this 4108 feet to the difference in elevation between Helena and Boulder we get the height of Boulder above sea level. Our finding is 4108 plus 815, equals 4923 feet.

In a previous paragraph mention was made of the effect of temperature on the air. The correction for this is laid out in two tables (pages 46 and 47) taken from the *Smithsonian Miscellaneous Collection.*

These tables need not be taken into consideration unless very accurate readings are required.

As an instance, suppose at the bottom of a mountain the temperature was 70° Fahrenheit and the hand on the barometer pointed at 2000 feet. The correction as noted at 70° Fahrenheit is 82 feet, which has to be added as have all temperature corrections above 50° Fahrenheit, making the indication 2082 feet.

Smithsonian Miscellaneous Collection No. 21.
For temperatures above 50°F. the values are to be added.
For temperatures below 50°F. the values are to be subtracted.

Temperature Fahrenheit		FEET OF ALTITUDE					
		100	500	1000	2000	3000	4000
49°	51°	0	1	2	4	6	8
48°	52°	0	2	4	8	12	16
47°	53°	1	3	6	12	18	24
46°	54°	1	4	8	16	24	33
45°	55°	1	5	10	20	31	41
44°	56°	1	6	12	24	37	49
43°	57°	1	7	14	29	43	57
42°	58°	2	8	16	33	49	65
41°	59°	2	9	18	37	55	73
40°	60°	2	10	20	41	61	82
39°	61°	2	11	22	45	67	90
38°	62°	2	12	24	49	73	98
37°	63°	3	13	27	53	80	106
36°	64°	3	14	29	57	86	114
35°	65°	3	15	31	61	92	122
34°	66°	3	16	33	65	98	130
33°	67°	3	17	35	69	104	139
32°	68°	4	18	37	73	110	147
31°	69°	4	19	39	77	116	155
30°	70°	4	20	41	82	122	163
29°	71°	4	21	43	86	128	171
28°	72°	4	22	45	90	135	179
27°	73°	5	23	47	94	141	188
26°	74°	5	24	49	98	147	196
25°	75°	5	25	51	102	153	204
24°	76°	5	27	53	106	159	212
23°	77°	6	28	55	110	165	220
22°	78°	6	29	57	114	171	228
21°	79°	6	30	59	118	177	236
20°	80°	6	31	61	122	184	245
19°	81°	6	32	63	126	190	253
18°	82°	7	33	65	130	196	261
17°	83°	7	34	67	135	202	269
16°	84°	7	35	69	139	208	277
15°	85°	7	36	71	143	214	285
14°	86°	7	37	73	147	220	294
13°	87°	8	38	75	151	226	302
12°	88°	8	39	77	155	232	310
11°	89°	8	40	80	159	239	318
10°	90°	8	41	82	163	245	326
9°	91°	8	42	84	167	251	334
8°	92°	9	43	86	171	257	343
7°	93°	9	44	88	175	263	351
6°	94°	9	45	90	179	269	359
5°	95°	9	46	92	184	275	367
4°	96°	9	47	94	188	281	375
3°	97°	10	48	96	192	287	383
2°	98°	10	49	98	196	294	391
1°	99°	10	50	100	200	300	400
0°	100°	10	51	102	204	306	408

TEMPERATURE CORRECTIONS FOR ALTITUDE SCALES

(Continued)

Smithsonian Miscellaneous Collection No. 21.

For temperatures above 50°F. the values are to be added.

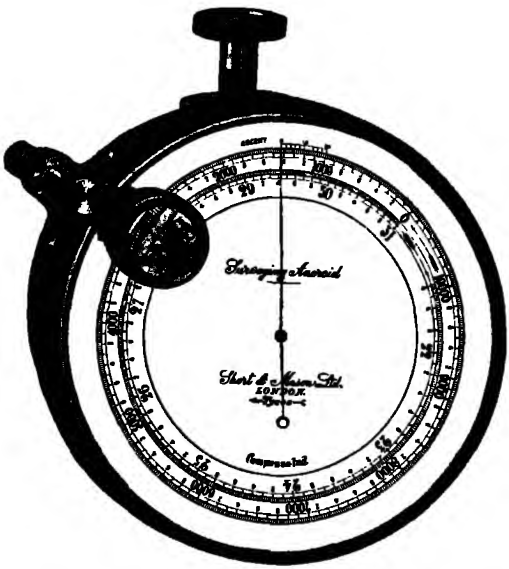
For temperatures below 50°F. the values are to be subtracted.

Temperature Fahrenheit		FEET OF ALTITUDE					
		5000	6000	7000	8000	9000	10000
49°	51°	10	12	14	16	18	20
48°	52°	20	24	29	33	37	41
47°	53°	31	37	43	49	55	61
46°	54°	41	49	57	65	73	82
45°	55°	51	61	71	82	92	102
44°	56°	61	73	86	98	110	122
43°	57°	71	86	100	114	128	143
42°	58°	82	98	114	130	147	163
41°	59°	92	110	128	147	165	184
40°	60°	102	122	143	163	184	204
39°	61°	112	135	157	179	202	224
38°	62°	122	147	171	196	220	245
37°	63°	133	159	186	212	239	265
36°	64°	143	171	200	228	257	285
35°	65°	153	184	214	245	275	306
34°	66°	163	196	228	261	294	326
33°	67°	173	208	243	277	312	347
32°	68°	184	220	257	294	330	367
31°	69°	194	232	271	310	349	387
30°	70°	204	245	285	326	367	408
29°	71°	214	257	300	343	385	428
28°	72°	224	269	314	359	404	449
27°	73°	234	281	328	375	422	469
26°	74°	245	294	343	391	440	489
25°	75°	255	306	357	408	459	510
24°	76°	265	318	371	424	477	530
23°	77°	275	330	385	440	495	551
22°	78°	285	343	400	457	514	571
21°	79°	296	355	414	473	532	591
20°	80°	306	367	428	489	551	612
19°	81°	316	379	442	506	569	632
18°	82°	326	391	457	522	587	652
17°	83°	336	404	471	538	606	673
16°	84°	347	416	485	555	624	693
15°	85°	357	428	500	571	642	714
14°	86°	367	440	514	587	661	734
13°	87°	377	453	528	604	679	754
12°	88°	387	465	542	620	697	775
11°	89°	398	477	557	636	716	795
10°	90°	408	489	571	652	734	816
9°	91°	418	502	585	669	752	836
8°	92°	428	514	599	685	771	856
7°	93°	438	526	614	701	789	877
6°	94°	449	538	628	718	807	897
5°	95°	459	551	642	734	826	918
4°	96°	469	563	657	750	844	938
3°	97°	479	575	671	767	862	958
2°	98°	489	587	685	783	881	979
1°	99°	500	599	699	799	899	999
0°	100°	510	612	714	816	918	1020

If at the summit the hand points to 6000 feet and the temperature is 20° Fahrenheit the correction will be 367 feet to be subtracted, making our elevation 5633 minus 2082, or 3551 feet.

This illustration shows a range of 50° Fahrenheit in temperature on an elevation of 4000 feet, so the correction is naturally a large one.

Altitude scales are ordinarily made to register from 3000 feet to 25,000 feet around their circumference. Naturally those reading to 3000 feet are divided into finer divisions than those of higher altitude.



Altitude barometer as used by surveyors. Reads to single feet of altitude.

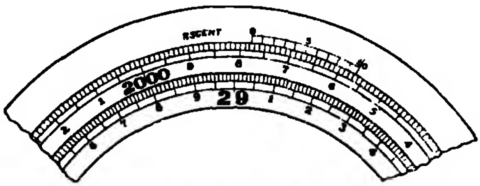
Certain types of barometers are constructed to allow a very fine subdivision of their altitude scales. In order to make this possible their mechanisms are altered so that the altitude scale can be divided into equal parts and the pressure scale into unequal parts, just as in nature.

A vernier rotates around their circumference and by its use it is possible to read to single feet of elevation.

The vernier was invented by a Brussels engineer, Peter Vernier, in 1631—quite a few years before the

barometer was invented. It really consists of a movable scale attached to a fixed scale, to measure spaces smaller than those into which the fixed scale is actually divided.

The vernier will be easily understood if the figure illustrated be explained. The scale upon which the figures 2000 appear represents part of a scale of altitude, divided into tenths and subdivided into



The Vernier scale

hundredths, so that each of the smaller divisions represent 10 feet. The smaller scale above, marked "ascent," represents the vernier and is movable around the other scale. The ten lines on the vernier scale exactly cover twenty-one divisions on the altitude scale, consequently each division of the vernier covers 2 1-10th divisions of the altitude scale.

If the "0" were to be moved around until it coincided exactly with the 2000 division, the first line on the vernier scale would point to the 2 1-10th division, the second to 4 2-10, the third to 6 3-10, the fourth to 8 4-10, the eighth to 16 8-10, the ninth to 18 9-10, and the tenth to 20 10-10 or 21.

It is clear that but one division on the vernier can coincide with a division on the fixed scale, at one time. The lines that exactly coincide mark the subdivision of the division.

The illustration shows the "0" at a point 1770 (imagining the scale be extended to the right so that the 1000 is perceptible), while the seventh line of the vernier scale is in alignment with the line on the fixed scale, making the true reading 1777.

THE EFFECT OF WEATHER CHANGES ON THE ALTITUDE SCALE

As the weight of the air is not constant in any one place, it frequently happens that a change in the weather (either an increase or decrease in air pressure) takes place during a long ascent of a mountain, which causes the hand of the barometer to travel either down or up the altitude scale.

This change in air pressure can, of course, be easily mistaken for an increase or decrease in the height travelled by the observer.

As an instance, let us suppose we remained at a certain point for twelve hours and that when we arrived the barometer showed 1200 feet on its altitude scale and when we departed 1300 feet. It is certain we had not risen 100 feet, for we remained at the same point.

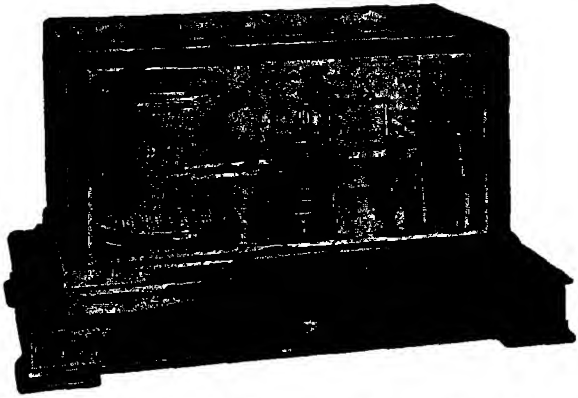
The change in reading of the scale is due to a change in atmospheric pressure, probably indicating the approach of a change in the weather.

Variations of this character are usually very small and extend over a good many hours, so for ordinary purposes they can be disregarded, but, when travelling it is advisable to note the point at which the barometer stands at night, so if by morning any change has taken place it can be taken care of.

Engineers, surveyors and others who need to take very exact readings, usually employ either an observer at the point they leave, to read another barometer hourly and note its changes, or else they use a "Stormograph" (recording barometer) so all the changes are automatically noted on a chart both as to the time such changes occur and their amount.

Note of the time they arrive at certain points and the reading of the barometer with them is made, so

when they return to their starting point or base, by consulting the "Stormograph" they can determine the exact amount to deduct from or add to their reading.



"Stormograph" or Recording Barometer combined with Recording Thermometer and registering on the same chart

Here is a simple example. Suppose a party started out at 8 a. m. on Monday with their barometers reading at 29.50 inches, the equivalent of 1350 feet on the altitude scale. By 10 p. m. the summit of a mountain had been reached and their barometer read 24.20 inches, the equivalent of 6750 feet on the scale. They would naturally compute their altitude in feet as 6750 minus 1350, equals 5400 feet. After resting the night they retraced their footsteps, arriving at their starting point any time on the following evening (Tuesday), having been away for approximately thirty-six hours.

By referring to their "Stormograph" record they find that at 10 p. m. Monday the barometer stood at 29.70 inches. (When they left it was reading 29.50 inches).

Now we see that at their base at 10 p. m. Monday the barometer read 29.70 inches, equal to 1150 feet on the altitude scale, and at the summit 24.20 inches, the equivalent of 6750 feet on the altitude scale, so the reading is 6750 minus 1150, or 5600 feet altitude.

THE THERMOMETER AND ITS FAMILY TREE

IN looking at a thermometer—apparently a glass tube containing either mercury or a colored liquid and placed upon a divided and figured plate of some description — one is not apt to realize the thought, skill and research it has taken to bring this simple, yet universally necessary article to its present status.

The Drebbel Thermometer About 1592

For many centuries scientists have worked in an endeavor to perfect it, but only during the past forty years have they found out all the details necessary to the manufacture of a more or less perfect article.

Many people are credited with its invention, Drebbel, a Hollander, being referred to more than any other, but to Galileo Galilei the laurels should be handed.

According to history it seems that about 1592 he invented at Padua an instrument described as "a glass containing air and water, to indicate changes and differences in temperature."

The Sanctorius Thermometer About 1620

With the idea started, the Grand Duke of Tuscany investigated this

"invention," and more or less perfected it between 1630 and 1640.

The original thermometer consisted of a glass tube about 16 inches in length with a hollow ball or bulb fitted at the end. The whole was heated until the air inside became rarified, when the open end was placed in water, the tube being kept upright.

As the air in the tube cooled or contracted, the fluid (water was originally used) in the tube rose to a certain point and any subsequent changes caused the level of the fluid in the tube to be either elevated or depressed.

This was used by Sanctorius as a "heat measure" or fever thermometer. It is on record that he had his patients hold the top of the "thermometer" so the level of the fluid would be arrested at a point equal to the temperature of the person holding it. A "point" was undoubtedly determined by a normal, healthy person beforehand and it is reasonable to assume that Sanctorious drew his deductions by noting the distance above or below this "normally healthy" point.

M. Jean Roy, a French physician of note, made a thermometer similar to the one originally designed by Drebbel, but filled it with alcohol instead of water. He did not invert his "thermometer," but kept it in an upright position and noted the rise and fall of the spirit due to the expansion or contraction of it. This was about 1630.

Before ten years had passed, the Grand Duke of Tuscany had carried out his idea of first partly filling the tube with alcohol and closing the open end, thus sealing it and excluding the air.

Realizing that the level of the liquids in these various instruments meant nothing, pupils of Galileo sought to make a scale of temperature and melted on

to the tube of their thermometers small glass balls about the size of a pin's head, the zero of the "scale" being the point to which the liquid fell in a freezing mixture of salt and water.

For the next hundred years or so the deepest confusion occurred, for not only had various types of instruments been invented, but no two of them agreed as regards their graduation. Many schemes and devices were used to determine satisfactory scales, but agreement could not be easily made.

In a book written in 1738 by Bernandinus Teleius great attention is given to this matter.

At one time, it seems the bright minds of Europe decided that the freezing point of liquors varied to such an extent that it could not be used as a test point, and suggested taking the temperature:

"In a cave cut straight into the bottom of a cliff fronting the sea to the depth of 130 feet, with 80 feet of earth above it."

Speaking of this, the author says:

"But with Dr. Hale's leave, this degree of temperature I do not think a very convenient term for universal construction of thermometers. Everybody cannot go to Mr. Boyle's grotto; and it is but few who can have an opportunity of making observations and adjusting thermometers in the cave of the 'Parisian Observatory'."

In speaking of the scale laid out by Sir Isaac Newton as having test points at freezing water, the heat of the human body, boiling water and melting tin, he says:

"I wish the world would have received this or any other determined scale for adjusting their thermometers, but I suppose they might be apprehensive of some inconvenience in this scheme."

Robert Hooke and Hon. Robert Boyle, of the "Royal Society in London," were the first to realize the neces-

sity of having a standard scale. About 1662, Hooke, placing his instrument in freezing distilled water, marked "zero" at the top of the column of spirit after immersion of the bulb. Soon after, he suggested that the second point should be the boiling point of water; but this does not seem to have been adopted at that time.

Delance suggested that the freezing point of water should be marked "cold" (–10°), the melting point of butter "hot" (+10°), and the space midway between "temperate" (0°), with ten divisions between each.

In 1714, Fahrenheit of Dantzig designed a scale for thermometers which showed the freezing of water at 32° and the boiling of water at 212°.

Many suggestions have been made as to why he graduated the freezing and boiling of water into 180 divisions, one being that as he was an astronomical instrument maker, and as his machines divided to full circles (360 divisions), he used a half circle for his scale.

Seventeen years later, Reaumur, a French physicist, designed a scale on which the freezing point of water appeared as 0 degrees, the scale between this and the boiling of water being divided into eighty equal parts.

Anders Celsius, professor of Astronomy at the University of Upsala, proposed a scale in 1742, and called the freezing point of water 100° and the boiling point of water 0. These points were afterwards reversed by Christin of Lyons (France) in 1743, and the result is the well known Centigrade scale.

Athanasius Kircher was the first to use mercury in thermometers, although Delance once remarked "curious people use it," little dreaming that one day it would become universal in use.

In speaking of the faults of different liquids used in the early manufacture of these instruments, Teleius remarks:

"We have, it seems, nothing left but mercury."

"This is a very movable, and ticklish fluid; it both heats and cools faster than any liquor we know of or have had occasion to try."

Mercury and alcohol have been accepted by the scientific world as a convenient and accurate means to indicate the temperature of anything with which the tube containing them may come in contact.

For high temperatures mercury is used, for it

FREEZES AT -38° Fahrenheit, -38° Centigrade.

AND BOILS AT 674.6° Fahrenheit, -357° Centigrade.

As the freezing point of mercury is fairly high, alcohol thermometers are invariably used in very cold climates, for this liquid

FREEZES at -202.9° Fahrenheit, -130.5° Centigrade

AND BOILS AT 173.5° Fahrenheit, 78.5° Centigrade.

From this it will be seen that mercury is unsuitable for any very low temperature and alcohol is unsuitable for any very high temperature.

THE CONVERSION OF THERMOMETER SCALES

Centigrade to Fahrenheit

To convert Centigrade degrees to degrees of Fahrenheit, multiply by 9, divide the product by 5 and add 32. When the temperature Centigrade is below 0 Cent. deduct 32 instead of adding.

Fahrenheit to Centigrade

To convert Fahrenheit degrees to degrees of Centigrade, subtract 32, multiply by 5 and divide by 9. When the temperature Fahrenheit is below 0 Faht. add 32 instead of subtracting.

Reaumur to Fahrenheit

To convert Reaumur degrees to degrees of Fahrenheit, multiply by 9, divide by 4 and add 32. When the temperature Reaumur is below 0 Reaumur deduct 32 instead of adding.

Reaumur to Centigrade

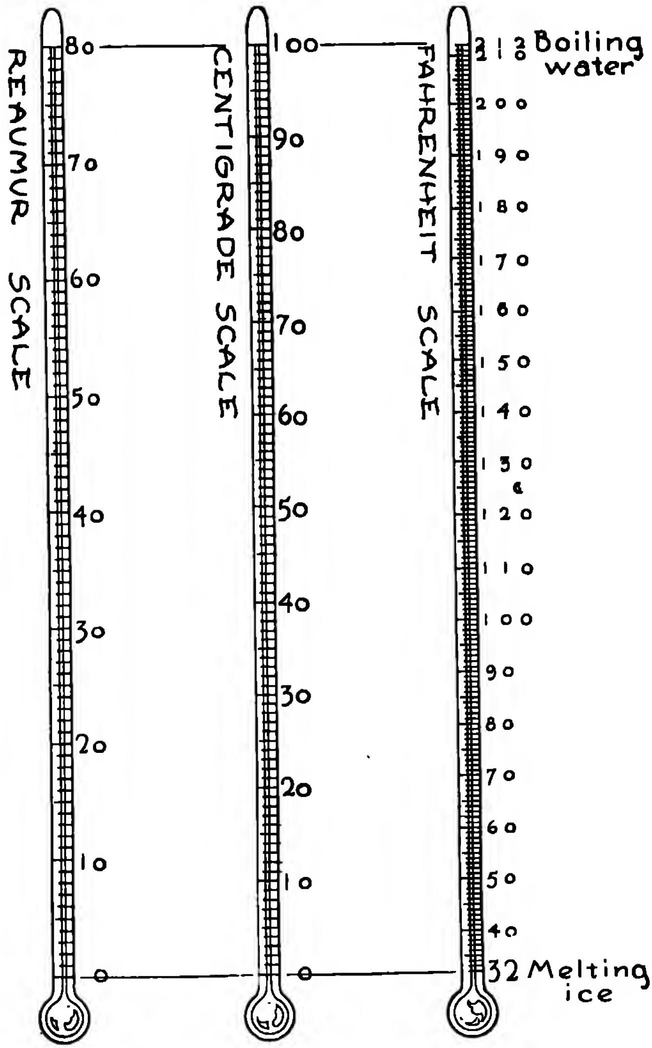
To convert Reaumur degrees to degrees of Centigrade, multiply by 5 and divide by 4.

Centigrade to Reaumur

To convert Centigrade degrees to degrees of Reaumur, multiply by 4 and divide by 5.

Cent.	Water Freezes at 0°	Faht.	Water Freezes at 32°
	" Boils " 100°		" Boils " 212°

Reaumur	Water Freezes at 0°
	" Boils " 80°

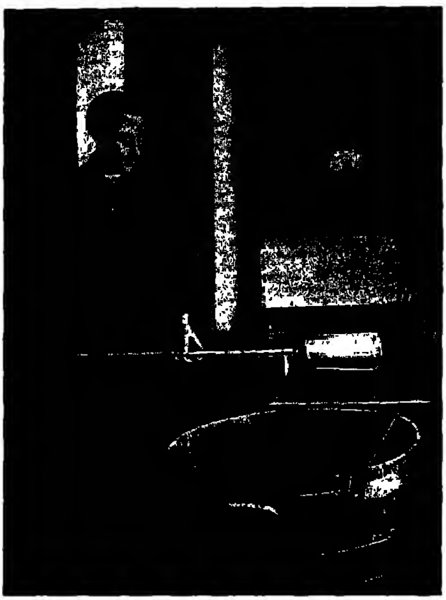


The Three Standard Scales for Thermometers

THE MAKING OF GLASS THERMOMETER TUBING

As the value of a thermometer depends to a great extent on the grade of glass and the care taken in making and drawing it into the tubes, a few words regarding it will be of help to the reader and will give an idea of how the small "hole" or "bore" up which the mercury travels is formed in the glass.

Glass is hard, brittle and transparent. It is formed by fusing together mixtures of silicates of potash, soda, lime, magnesia, alumina and lead in various proportions, according to the quality or kind of glass required.



Rolling the Glass Mass

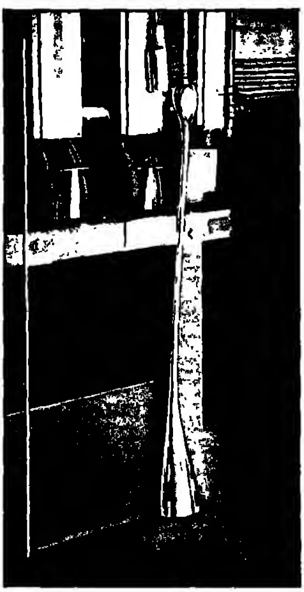
The first step in the manufacture of glass tubing is to take an iron pipe, about five feet long, and collect on about two inches of the end of it (by dipping it in molten glass) a quantity of glass about as large as a quart milk jug. When this glass is still in a plastic state (i. e., not hard) a bubble is formed in the centre of it by blowing hard into the end of the iron pipe. The glass is then rolled over a plate so it becomes cylindrical in shape but solid, except for the hole in the centre

caused by blowing through the iron pipe. This rolling process causes the roughly blown round hole in the glass to attain a cylindrical shape—more or less perfect in appearance.

The next process is to flatten the glass, which is accomplished by applying pressure to the top and bottom of the mass. This operation causes the cylindrical hole in the centre to flatten out a trifle, due to pressure, and to appear in the shape of a thick ribbon instead of a circular hole.

White enamel glass is then put on that part of the tube which is directly behind the "hole" or, as it is called in the finished thermometer, the "bore."

The mass is now put into hot glass so it is absolutely covered with a new coat of it. During all these processes the glass develops "waviness" and to get it into proper condition and solidity it has to be rolled on iron slabs. The outside is chilled somewhat, so the inside retains its correct shape.



Drawing Plastic Glass Into Tubes

In order to properly read the mercury in the column, a great many tubes have "lens" fronts. This lens is formed on the glass by putting it in a "V" shaped mould with the white enamel glass uppermost. The mass then represents a wedge with a rounded top.

Now remember what has been done to this glass to make tubing from it. A hole has been blown in the centre

of the original "lump" of glass; it has been rolled out, flattened on the top and on the bottom, it has had white enamel put upon the back, and has been covered with a second coating of glass. Finally it has been rolled again to take imperfections out and then the lens has been formed on the front.

At this point it looks like a piece of glass tubing about 5 inches thick and 9 inches long, on the end of an iron tube with a long bubble in the centre, some white glass behind the bubble and the glass formed in a "V" or wedge in front of the bubble.

Now the delicate operation comes of "pulling this glass out"—or "stretching" it into the small thin canes of tubing such as are used in thermometer making.

The mass of glass is put on a hot iron plate—six or eight inches in diameter, with the iron tube through which the hole was blown pointing upwards. This tube is secured to a wire cable, which extends upwards for about 150 feet, and is attached to a motor.

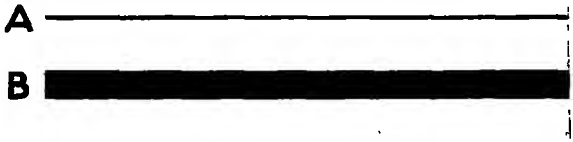
The glass is now ready and the motor is put in operation, with the result that the plastic glass is pulled upward for about 150 feet into a more or less perfect tube.

The hole which was originally blown in the centre becomes the minute hole up and down which the mercury travels—the white enamel glass becomes the white back of the thermometer tube, and the "V" front becomes the magnifying lens.

The tubing is now ready for cutting up into "canes," or lengths of glass, to be used for tube making. The ends of the length after drawing are useless, due to distortion in forming them.

Great care has to be taken in sorting this glass, for the size of the hole or "bore" in the centre of the glass varies, and as a consequence mercury or spirit will

rise slowly up a tube having a large bore, and quickly up a tube having a small bore, if the bulb or mercury ends of the thermometer are of the same size.



A Thermometer Bore
B Human Hair

In some thermometers the "bore" is very much finer than the diameter of a human hair, and the relation of the capacity of the bulb which holds the mercury to the tube up and down which it travels, is roughly 1000 to 1.

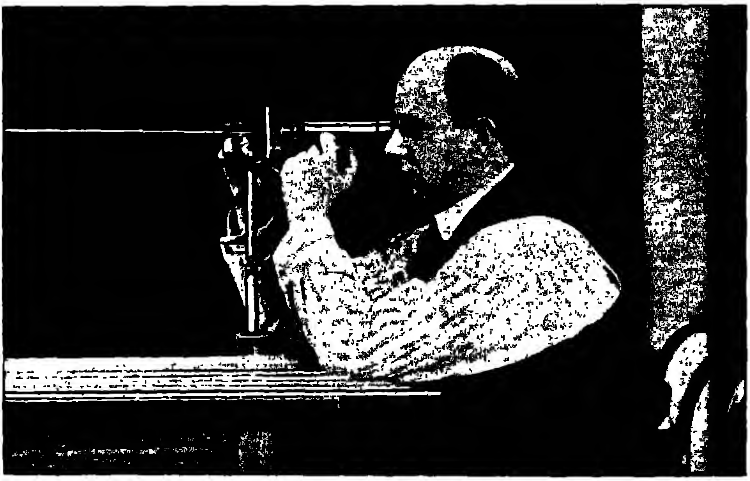
The "grading" of these tubes calls for the work of an expert, for it can only be done by putting the end of the glass to a powerful microscope and measuring the "bore" by means of hair lines under magnification.

This practically completes the making of glass tubing.

THE MAKING OF THE THERMOMETER TUBE

The lengths of glass tube, or "canes" as they are called, are now cut into pieces twice the length of the thermometer into which they will ultimately be made.

The tube is held with its centre in the sharp flame of a blow pipe. When it has become warm enough it can be pulled apart, making two complete tubes, each of the same length and each sealed at one end.



Measuring the Bore of a Tube

One of these tubes is now taken and a rubber bulb is attached by a small hose to the *open* end.

The *closed* end is now heated, pressed and manipulated until the glass is more or less solid at this end. The rubber bulb is pressed, forcing air down the tube and when it reaches the molten end a bubble is formed. This bubble is called the bulb. See illustration page 66.

In the manufacture of certain grades of thermometers special hard glass is melted on to the end of the tube, so that the bulb is formed from this hard glass instead of from the tube glass.

Sometimes these bubbles or bulbs are made large and sometimes small—depending on what is required of the finished thermometer. If the bore in the tube is large and the bulb large, or the bore in the tube is small and the bulb is small, the mercury will rise much more slowly in the tube than if the bore is small and the bulb large.

Every tube, therefore, having a certain bore must have a certain sized bulb to make it work in a particular manner. If it were required to create a thermometer in the Fahrenheit scale with the "freezing" at a certain point—say ¼" from the bulb, and a 120° point, say ¼" from the top of the tube, the bore of the tube would have to be measured and the bulb would have to be of a certain exact size.

It is possible with a microscope to measure the bore accurately and it is possible to determine the size the bulb should be, but it is impossible to make it work so that at certain temperatures the mercury would stand at a number of predetermined points on the tube.

Filling a Tube With Mercury

Plates having different sized holes in them are supplied to the tubemakers and with the workman's knowledge of the size of the bore, the approximate size of the bulb can be determined when they know the lowest point and the highest point the thermometer will be required to register. For instance, a bulb ¼″ in diameter might, if fitted to a tube having a certain bore, have a range of scale showing 200° from its highest point to its lowest point. If the bulb was made ½″ in diameter, the range of scale might be equal to 50°.

After the bulb has been formed to the correct size, and while it is still hot, the open end of the tube is placed in a jar of pure, clean mercury. As the glass cools, the air in the bulb and tube contracts, drawing the mercury up into it.

This process will only partially fill the tube and in order to complete it, the tube after cooling is taken out of the jar, and with the bulb downwards more heat is applied, when it is again inverted in the jar and so on, until the bulb and tube are completely filled.

A process known as "roasting" is carried on, to expel every particle of moisture.

In order to properly seal and close the tube, a gas flame is blown across the top of it until the glass be-

Blowing and Gauging the Bulb

comes very plastic. The top of the tube is now drawn away in exactly the same way as it is drawn in the original manufacture—very thin—but still having a very minute hole or bore in the centre.

Heating the bulb again drives the mercury to the top of the tube once more and it travels along the newly made thin tube, expelling all the air. If the glass at the extreme top of the main tube, or at that portion of it which starts to thin out by the last operation, be melted, it will seal this hole and, providing the operation is accomplished carefully, will prevent any air from entering the thermometer. The mercury will flow back to the bulb of the tube as it cools.

This end, turned to form a hook, is used to fasten the thermometer tube on its scale, so it will not slip up or down.

The thermometer tube is now complete, for a bulb has been formed at the end, the tube and bulb have been filled with mercury, the air expelled and the end sealed. The mercury is now free to move up and down the tube as soon as temperature changes either expand or contract it. When the surrounding air gets warmer the mercury expands and rises in the tube and when the surrounding air gets cooler it contracts and falls.

Yet—although we have our tube made satisfactorily, with bulb and mercury, we have not a thermometer, because the height of the mercury in the tube at any temperature has not yet been determined.

To properly accomplish this it is necessary to have water in receptacles of different temperatures, one at 32° Faht., one at 62° Faht., and another at 92° Faht., if the thermometer is to be used for ordinary room temperatures.

The 32° Faht. point is obtained by crushing ice, as 32° Faht. is the temperature of either freezing water or melting ice. A point 2° Faht. is obtained on some thermometers, being reached by a brine solution.

In each of these "baths" a thermometer of known accuracy is placed and left immersed a sufficient time to enable the mercury to come to rest, thus determining the correct temperature of the water, which must be constantly agitated, in order to keep it from becoming cooler on the sides than in the centre, or vice versa.

In thermometer manufacturing water is mechanically controlled at the necessary temperatures, but if by chance it should rise or fall below the desired point, it can be readily adjusted by introducing either cold water or steam.

If the bath is controlled and has a temperature of 62° Faht., the thermometer tube which has to be tested is put in and, when the mercury has come to rest, a line is put upon the tube at the level of the mercury, thus indicating the point at which the mercury stands when the temperature is at 62° Faht. This operation is repeated in a bath of 92° Faht., and also in crushed ice at 32° Faht. A point 2° above zero Fahrenheit is reached in cold brine.

Four marks, divisions, or "points" as they are called, have now been determined and if they are equidistant it is reasonable to assume that each one can be subdivided into thirty equal divisions, i. e., from 2 to 32, from 32 to 62, and from 62 to 92. The divisions can be extended below 2 and above 92 at the same ratio with reasonable accuracy.

A brass plate is now taken, which when completed will form the scale or face of the thermometer, for upon it the graduations have to be placed — also the figures.

The thermometer tube is set upon this plate and the marks which denote 2°, 32°, 62°, and 92° Faht., are reproduced in exactly the same positions upon it. A dividing machine is arranged to cut or engrave the necessary divisions upon the scale which can be finished

in any desired style before the thermometer tube is permanently placed upon it. Finally great care must be exercised in seeing that the points on the tube agree exactly with the same points on the scale, before the finished thermometer is packed for shipment.

This completes the manufacture of a common type of thermometer. Refinements in manufacture are many and there are various and obvious reasons why a thermometer apparently looking the same as another should cost two, three or even four times as much. But we will not attempt to go into the special features of such thermometers in this book.

ERRORS WHICH MUST BE GUARDED AGAINST

Manufacturing

(A) Careless "pointing" of the tube will, of course, result in erroneous readings and it is one of the most common sources of trouble in practical thermometry.

This can be caused through inefficient labor, through carelessness in placing the points upon the tube, or in letting the test baths get either too cool or too warm, during the pointing process.

Occasionally the thermometer tube will slide from its position on the scale and naturally all indications will be reading either above or below the true reading.

(B) If the bore of the tube is erratic, the mercury will naturally rise more slowly in parts which are larger, and faster in parts which are smaller.

The theory of this was pointed out on page 65, which explained the connection between the bulb and the bore. The smaller the bore the quicker the rise of the mercury in the tube.

(C) Impurities in the mercury make the bore of the tube rough and if the mercury is dusty, particles of it

will stick to the bore of the tube, and besides being unsightly it will cause the mercury to appear sluggish in its action.

(D) As glass shrinks after manufacture, it is necessary in order to have a thermometer keep its readings correct, to make sure the glass is properly "seasoned."

The shrinkage of glass is imperceptible, but it is easy to realize that if the bulb and bore of the tube contract the smallest amount, the mercury will be driven higher in the tube, so that a point, say 40° Faht., might be correct on the scale made for the tube when new, but after the tube had contracted, or shrunk, or become seasoned, might read 46° Faht., or even 48° Faht., depending on the quality of the glass. The only way to overcome this is to keep tubes in storage for eighteen or even twenty-four months before determining the "points," so that all contraction of the glass will have passed and the indications will be permanently accurate.

BLUNDERS WHICH CAN BE AVOIDED

Observing

(A) Nothing is so disheartening to an observer of temperature, noting temperature of a room, the soil, the outside air, or whatnot, as readings which he feels he cannot rely on.

Naturally it is essential in the first place that the thermometer being used is of known accuracy and will remain so. A little extra cost in the original purchase of a thermometer will never be regretted.

(B) All thermometers are affected by the surrounding air. When observing the readings be careful not to stand so near the bulb that it will be affected by the warmth of your body or breath. This is a continual source of trouble, especially if the thermometer be a very sensitive one.

(C) Take great care in noting the proper division on the scale. Some thermometers have their divisions in 2° lines, some in 1° lines, some in ½° lines and some in 1-5°, 1-10°, etc. Errors are often made in reading 2° lines as 1° lines.

(D) In reading be sure and get the eye level with the mercury. If you read it from below the reading will appear too high, and if from above too low.

(E) In moving a thermometer into a fresh place remember it takes some time for it to adjust itself to the new temperature. This, of course, depends on the sensitiveness of the instrument. Fanning it, or passing it carefully through the air for some time will greatly help it.

(F) Beware of the word "Standard!" It is a most abused term! The word is placed on some thermometers that are not standard in any sense of the word. In experience the writer has found thermometers marked this way with errors varying from 3° to 10° Faht.

(G) Do not condemn a thermometer because it does not agree with one hung near it. Remember these instruments indicate the temperature of the air which surrounds THEM and NOT the temperature of the air one inch or twelve inches away.

TYPES OF THERMOMETERS

The style of thermometer ordinarily used for the purpose of determining the temperature of rooms, offices, corridors, etc., is one having a metal plate with the thermometer tube set upon it, the whole being fitted to a wooden back, of varied styles and descriptions.

Room Thermometer

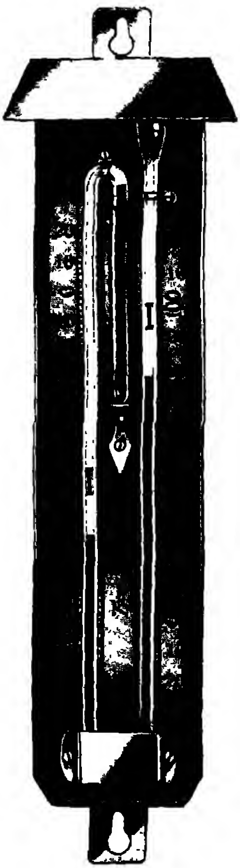
Such a thermometer is very satisfactory, providing it is not influenced by direct sunshine, draughts, open windows, radiators, air furnaces, etc. Care should be taken when fitting it on the wall to see that no chimneys or air shafts pass through that part of the wall, causing it to be excessively hot or cold. When convenient a thermometer should be set two or three inches away from a wall, so that it may get correct circulation of air around it.

The most satisfactory height for a room thermometer is about 60 inches to 70 inches above the floor. Thermometers having colored alcohol in them in place of mercury can be much more quickly read, although slightly slower in their working, than those in which mercury (quicksilver) is used.

Sometimes some alcohol may become separated from the main column, but it can be easily joined to it by swinging the thermometer sharply backwards and forwards with a pendulous motion, taking care that the bulb is downwards. It is also desirable to occasionally examine the upper part of the tube and to see that it is perfectly free from detached portions of alcohol. An easy method of correcting this is to take the thermometer with the bulb in the right hand and strike the top against the palm of the left hand. The alcohol at the top of the tube will slowly start to run down towards the main column. When detached portions are joined,

the thermometer should be allowed to stand in an upright position for about half an hour.

This simple form of thermometer gives indications of existing temperatures. In sick rooms, greenhouses and many other places, it is interesting and sometimes necessary to have a knowledge of past temperatures. For this purpose a thermometer capable of giving maximum and minimum temperatures is used. The one most common, interesting, and effective is a pattern designed by Mr. James Sixe, of Canterbury, England. It consists of a glass "U" shaped tube with the ends terminating sometimes in round balls and sometimes in a ball at one end and a glass cylinder at the other. The latter pattern is in all ways preferable. The tube is completely filled with creosote to within almost one-half inch of its top, which is filled with air. Prior to this mercury has been put into the lower portion of the "U," but NOT for the working member, as popularly supposed.



High and Low Thermometer, "Sixe's Type"

If the illustration be examined it will be found that the left side scale is figured from 120° at the bottom to 40° at the top, while the right hand side is practically the reverse of this.

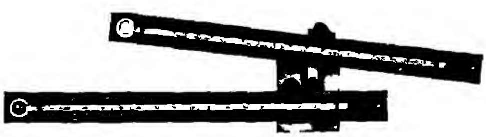
The creosote in the tube in the centre expands when the temperature increases, driving the mercury down on the left hand side and up

on the right hand side, thus increasing the air pressure in the right hand bulb. As the right hand side shows an increase in its scale reading it is called "Heat or Maximum" side of the tube.

If the temperature lessens, the creosote will contract so that the mercury will fall on the "Heat" side and rise on the "Cold" or "Minimum" side, which shows the thermometer scale decreasing.

Indices are carefully made and inserted in the tubes above the levels of the mercury, so they can be used to indicate the highest and lowest point the thermometer has reached since its last setting.

The index is a miniature glass bottle with a small piece of steel wire inside it. Steel is used so that the index can be raised or lowered by means of a magnet, which can be moved up and down in front of the tube. In order to keep the index from receding with the mercury, two hair-like appendages are fitted to it (one of these is fastened to the bottom and points upwards, the other is fastened to the top and points downwards). As the mercury rises on either the "Heat" or "Cold" side, the index is raised on the surface of it, and when the mercury recedes the index remains stationary until reset with a magnet. It will then indicate the highest and lowest reading since its last setting.



High and Low Thermometers. Horizontal Type.

Another type of thermometer to give maximum and minimum temperatures is shown above. This consists of two separate thermometers set horizontally, one to give maximum readings and the other minimum. The maxi-

mum instrument is mercury-filled, the tube being arranged in such a manner that when the temperature cools the mercury cannot, by itself, set back into the bulb. This allows it to remain indefinitely in the tube until reset. To reset it it is necessary to swing it sharply a couple of times, when the mercury will easily and quickly be driven back into its bulb.

The minimum thermometer is alcohol-filled and has a small index set in the fluid. By holding the thermometer upside down this index will flow down the alcohol to the end. It should now be placed horizontally. When the air cools the alcohol is naturally drawn toward the bulb, bringing the index with it. When it rises again the index is left stationary in the tube, indicating the lowest, or minimum, temperature. To reset it, invert the thermometer, when the index will flow again to the end of the alcohol column.

As they are of approved standard type, the thermometers tubes have the temperature divisions etched upon them. This is duplicated every 5° or 10° on the scale itself.

Any thermometer marked "Standard" and not having its scale divided and etched directly on the tube itself, is not a standard thermometer. Standard thermometers are always accompanied with a certificate of correction which shows the error (if any), so that true readings of temperature can be arrived at.

Thermometers with brackets are made for exposure outside of windows, so that outside temperatures can be read from inside.

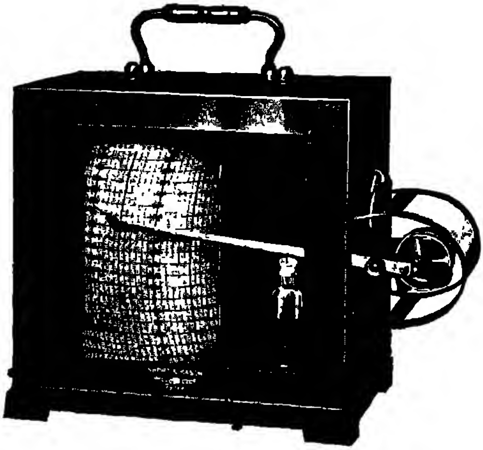
The figures on the scale are either etched permanently upon the glass or are painted upon it and baked in, so that water, snow, sunshine, etc., will neither fade nor wash them out.

Such thermometers are usually fitted outside the window, the metal arms allowing them to be held far

enough away to prevent the warmth (in winter) from the window affecting them.

A northern exposure is the best if it can be found, for the sun will not then upset the readings of the instrument, as will be the case if it be exposed on the south, where the sun will, when out, always shine upon it.

In some instances it is necessary to have knowledge of what the temperature has been during any previous period, or for any particular time. An instrument known as a "thermograph" or recording thermometer, is used for this purpose.



Instead of using a mercury or alcohol thermometer the working part consists of a spiral metallic coil, which is very sensitive to changes of temperature. To this coil is fitted an arm, about seven inches long, to the end of which is fitted a pen which registers on a drum (containing a clock) the different changes as they take place.

The clock rotates upon its axis once a week and has wrapped round it a chart on which are divided the days of the week, each day being divided into two-hour spaces.

The pen on the arm rises and falls as the temperature increases or decreases and as the clock revolves a tracing is made on the chart, which also indicates the time at which such changes occur.

In a greenhouse, sick room, or anywhere where temperature is of consequence, the information one gains by consulting the ordinary thermometer is not sufficient, for in the case of the greenhouse, the thermometer early in the morning may show 45° Faht., but who is to know the extent of its fluctuations throughout the night or if it went to or below the freezing point, killing all the young growth which was being so carefully guarded?

The same applies to the sick room. It can be easily seen if the temperature of the room is being maintained, or if it is fluctuating materially.

Records can be filed and kept for reference, for one never knows when such information may be needed.

There is one type of thermometer which can be found in the most remote parts of the earth—in the frozen Arctic and in the sweltering tropics,—men never travel without it. It is used among the uncivilized as well as the civilized, by all races of mankind, irrespective of color or religion. It is called the "fever" thermometer.

It is a well known fact that during health the same degree of temperature is virtually maintained. No matter whether it be winter or summer, our bodies contain the same amount of heat if they be in a normal, healthy condition.

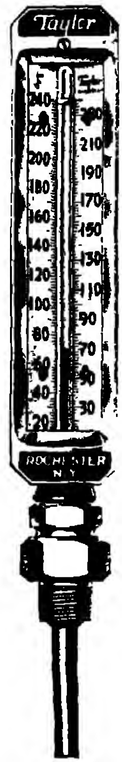
They not only contain it, but do so with a beautiful and natural exactness.

The temperature of a human being is not the same in all parts of the body, so, to establish a common standard, the medical fraternity accepted the temperature as taken under the tongue.

In some cases (such as in young children and those suffering from delirium), this is not a practicable place, so the rectum, or a point under the arm is selected, although the latter is not a very satisfactory point of contact, on account of the time the instrument takes to register the maximum temperature.

Fever Thermometer.

From a vast number of observations, a point 98.6° on the Fahrenheit scale has been determined as "Normal health." If the thermometer should rise or fall, or fluctuate from this point, the delicate mechanism of the body is in some way deranged. Some people are "subnormal" and others "abnormal," meaning that their individual and correct temperature is a fraction of a degree below or above the 98.6° Fahrenheit.



Industrial types of thermometer for determining temperature in various industrial applications.

The "average," as are all averages, was probably determined from a good many thousand readings.

Fever thermometers are made to register the maximum temperature by leaving the bulb end under the tongue for 2 minutes. The tube is made in such a manner that while the mercury will rise in the tube as the temperature increases, it will not recede or drop back after it is taken from the mouth and becomes exposed to a lower temperature. This is called a "self-regis-

tering" feature and it is necessary after each observation to hold the thermometer firmly by the upper end with the bulb downward and swing or shake it in such a manner as to force the mercury back toward the bulb.

The instrument should be carefully cleansed after each reading, to prevent the spread of any infection, and should be kept in as sanitary a case as possible.

Since a fever thermometer must be and must remain of absolute standard accuracy, it is easy to see that good ones cannot be cheap in price and that they cannot be purchased for a "mere trifle."

If the glass is not properly "seasoned," if the "points" are not most carefully determined and if the scale is not accurately divided, the instrument is more than useless.

An accurate fever thermometer is of untold value in a house, hospital or travelling kit, but an inaccurate one is a positive danger to the owner.

Thermometers for specific purposes have to be manufactured in a certain manner, both as regards their style and adjustment. A thermometer is always a thermometer, but it is impossible to make a single thermometer to cover a multitude of purposes. For instance, a thermometer used to indicate room temperatures is quite impracticable as a thermometer for indicating the temperature of the various mixtures used in candy making.

Thermometers are used in the manufacture of asphalt, candy, coal, oil, wood drying, tobacco, milk, artificial teeth, dough, ham, ice cream, maple and ordinary sugar, and are used in connection with babies' food, the bath, brewing, incubating, cold storage, fruit evaporating, hop curing, milk testing, photography, the soil, hot water heating, milk pasteurizing and sterilizing, orchards, railway coaches, refrigeration, veterinary work, vulcanizing, and a thousand and one other purposes, each one being of special design and especially adapted for its individual use.

HUMIDITY
ITS EFFECT ON OUR HEALTH AND COMFORT

THE variable climate of the United States has led to many devices being developed for the heating of houses, theatres, factories and offices. These devices as heat producers only, are probably perfect from a mechanical standpoint.

The designers and manufacturers of these devices have had in mind the production of heat only, and from a scientific and hygienic standpoint their value is not so great as one would imagine.

The air we live in is never perfectly dry. We speak of it as being "dry," "very dry," or "damp," but the dryness is at most only comparative. Watery vapor is constantly being distilled into the air from the great water surfaces—the oceans, rivers and lakes, and a very small percentage from the moist soil.

Moisture, rather than temperature, accounts for those oppressive debilitating, muggy and uncomfortable days we so often experience in the summer-time.

Lack of moisture not only causes discomfort, but accounts for a large percentage of catarrh, colds and other diseases of the nose and throat.

Moisture is Nature's great bed blanket to keep her children warm. Take the "blanket" away—or "thin" it out" and we all get cold. Without moisture we cannot live.

In our modern inside living temperatures we are apt to get an excessive amount of heat and an insufficient amount of moisture.

Heat as indicated by the thermometer is not at all the solution of the problem of "warming the house." The healthy human being maintains an internal constant temperature, if he be in the tropics or at the poles. Irrespective of surrounding temperature conditions the human body is always throwing off its excessive heat to the surrounding air.

To be at all comfortable, or to feel "comfortably" warm, we must see that the heated air has in it the proper percentage of moisture. In the average heating device no provision is made for moisture; when it is, it is so insufficient and inefficient that it can be entirely disregarded.

Nature, except in a few isolated instances, provides us with sufficient moisture to enable us to live comfortably in natural conditions. Habits in the last century have produced today a race of people extremely sensitive to heat and cold. Luxuries have now turned to necessities and with them we have to adjust our bodies to meet existing conditions.

Surely our houses are positive proof of this. The average temperature of the average house in winter is at least 72° Faht., and often quite in excess of this. This makes living conditions positively dangerous, as we will see.

In Rochester, N. Y., the average January outside temperature for the past 30 years is 24° Faht., the average humidity for the same period is 78%. This means that the air is 78% saturated with moisture. The average house temperature is, let us say, 72° and certainly the humidity in the winter under ordinary heating conditions never exceeds 22%.

Air which is low in its percentage of moisture is a great drier. We know this, for we hang clothes in the air so that the gentle winds can steal their moisture; sometimes with delightful rapidity, at other times

without any success at all. A laundress knows this as a fact, but is ignorant of the scientific reason.

Let us take a sponge, for example. We know well that a sponge can hold only so much water and that when it becomes saturated and more water is added, it "leaks," so to speak. The drier it is the more quickly it takes up water. So with the air. "Dry air" will steal moisture and hold it, far more rapidly than "moist" or "very moist" air.

We must not imagine that air will always take up the same amount of moisture. It will not. It depends upon its temperature. Cold air will not carry as much moisture as warm air.

It is easy then to see that if our rooms, without any artificial heat in them, have a temperature of, say, 40° Faht. and are warmed up to 70° Faht. or above, without the introduction of additional moisture, conditions are distorted seriously—even dangerously—as the percentage of saturation decreases with the increase of temperature. We may have 70 parts of water in the air at a temperature of 40° Faht., and when this temperature is raised to 70° Faht., by certain heating methods, the percentage of saturation is probably reduced to about 20 parts.

We know that dry air steals moisture and that warm air can take more moisture than cold air.

What then is the result of these manufactured heating conditions? The warm, dry air of the room steals the moisture from our bodies—dries us out as it were—the same as wet clothes are dried out on the clothes line. In other words, the moisture of our bodies evaporates into the air very rapidly at the surface of our skin. As evaporation causes the loss of heat, it is quite easy to see why we feel chilly, cold, or uncomfortable with the thermometer up in the seventies, Fahrenheit.

In the summer, with the thermometer at 70° Faht. we have sometimes noticed how excessively hot it

seems. Yet in the winter in our homes, with the thermometer at the same point, we sit with windows and doors shut tight to keep out the cold air, and shudder.

The reason for this is the great amount of moisture in the air in the former instance, and lack of it in the latter.

With a great amount of moisture in the air, perspiration does not evaporate quickly; that is, the very moist air cannot dry up quickly enough the moisture thrown off by the body. This prevents our body throwing off its excessive heat and as a consequence we feel it as heat. If it is thrown off too rapidly we feel it as cold. We cannot successfully dry clothes in the air on a damp day.

Excessive dryness has a startling effect upon the lungs and the delicate lining membrane of the throat and nasal passages. These passages are affected to such an extent that breathing is impeded and the tendency to disease developed.

The moisture in the air is like a great bed blanket. Take it away and we feel cold. Increase the heat and we feel colder, for evaporation from our skin increases.

The air of houses or rooms, public offices, theatres, etc., heated to this severe degree, besides seriously affecting the health of people in them, will shrink and damage furniture, books, pictures, etc. Cracks in the cabinet work of houses, and the checking of furniture are caused solely by the dry air drawing out the particles of moisture.

We can go to almost any museum or art gallery in the country and find that when rooms are heated by artificial means, great attention is paid to the moisture conditions, for a picture worth thousands of dollars would be fit only for the scrap heap if it became "dried" out; the paint would strip from the canvas and as an art treasure it would become worthless. Do we pay more attention to antique furniture, pictures,

mummies, etc., than we do to our own bodies? It certainly seems so.

Authorities have truly stated that 25% of the cost of heating our houses has been expended in raising the temperature from 62° Faht. to the unhygienic 72° Faht.

Who has not complained in the winter time of a room being too cold at 65° Faht. and yet in the spring or summer such a temperature is most comfortable.

The solution lies in the moisture. A room at 65° Faht. with a very small percentage of moisture in it feels a good deal colder than a room at the same temperature with a greater amount of moisture. Accordingly we oftentimes sit out of doors in comfort when inside at the same temperature we shudder with the cold.

The common practice of looking solely at the thermometer as an indication to health and comfort is therefore inadequate and very misleading. We have plainly seen that the temperature at the same point produces varying sensations of cold and heat, depending on the amount of moisture in the air.

It is ridiculous to lay down a fixed standard of temperature for comfortable living, without due regard to the moisture. Study the hygrometer also.

Apparatus of various designs, all supposed to increase moisture percentage in the house, have been brought out from time to time.

Without the installation of humidifying equipment one of the most satisfactory ways to "humidify" a steam-heated house is to place a rough, thick wet towel—preferably a bath towel, on account of its size and texture—over the radiator and leave it there long enough to dry out. It can then be moistened again, and as many times as desired. If hung over the back of the radiator it will not be so unsightly as one would imagine.

If air is used for heating, a possible way to moisten is to open the register and put in a lot of soaking wet muslin, such as an old sheet, and allow the heat to pass by it, so that the air instead of being delivered dry into the room, is moisture laden.

Of course, the most satisfactory method is to have some contrivance in the furnace jacket itself, such as pans, where the water surface will be large and the evaporation rapid. Twenty gallons a day has been evaporated by this method.

By these means the percentage of moisture has been constantly held at 54% when the temperature of the room has been 66° Faht. or a trifle over.

Don't attempt so much to increase the heat, but give more attention to the moisture.

Even boiling a kettle in the room will increase your comfort, but the carrying out of such an idea is not always practicable.

With all our attempts to improve health by lectures on the subject, standardization of food products, medical treatment, etc., it is amusing to note how very uninterested a great many people really are, for they complain that "to moisten the air makes the windows sweat." It is quite true this happens, but surely some of us still remember the winter morning when our windows were frosted inside because there had been moisture in the air and it had condensed on the cold panes and frozen.

Our present methods of heating produce an extreme "dry" heat, making it practically impossible for condensation to take place.

We're surely more thoughtful for our little inside plants, or ferns. You have often said "this room is too hot for this plant," little thinking that it was rather "lack of moisture" than excess of heat." You cannot grow many plants in the temperate zone in dry sand, for that is practically what earth becomes when it is devoid of moisture and is what it becomes as regards

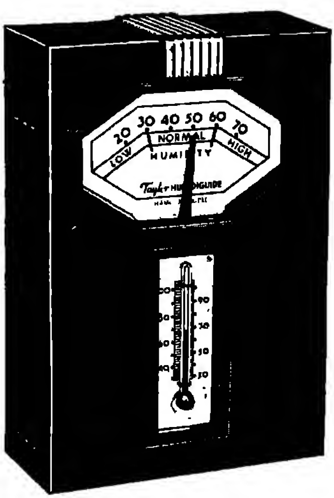
its growing qualities in our manufactured inside living climates. When plants droop we water them—give them more moisture—just what we need ourselves.

The slightest motion of over-heated air (when it is chilly and dry) causes an immediate search for suggested draughts, but when the humidity and the temperature are correct, or in balance, most comfortable conditions exist, for the air feels warm and balmy, the feeling of oppressiveness disappears and an indescribable sense of relaxation and poise immediately takes possession of us.

HYGROSCOPES AND HYGROMETERS

THERE are many things met with in our everyday life which are very sensitive to changes in moisture. These are known as "Hygroscopes" and include—wood, quill, hair, whalebone, animal membranes, whipcord, catgut, wild oat, common feather, grass, moss, and the internal membrane of the common reed.

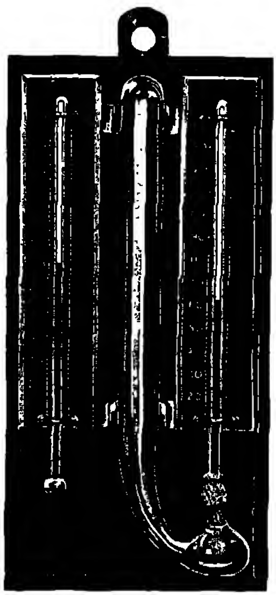
While these things are sensitive to changes in moisture conditions the only absolutely dependable type of instrument for this purpose is one known as a hygrometer, or moisture measure, or wet-and-dry-bulb thermometer.



A self indicating type of hygrometer, known as a Humidiguide has been developed for those people who require a direct reading instrument. In using this it must be remembered that it is slower in registering changes in moisture conditions than those hygrometers of wet and dry bulb type.

The wet and dry bulb type of hygrometer consists of two thermometers of known accuracy, mounted about four inches apart on wood, or metal, in such a way that the thermometers are not affected by the temperature of the mount.

One of these thermometers has its bulb "free," or exposed to the air temperature, while the other has its bulb covered with wicking or muslin, the end of which is immersed in a cup or tube of clean, distilled water.



Mason's-Form Hygrometer

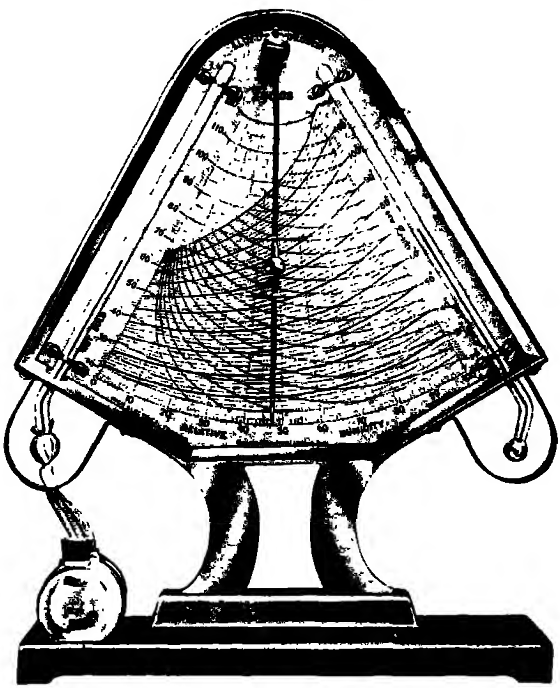
By capillary attraction this bulb is always kept moist and indicates the cooling effect of the evaporative power of the air.

The drier the air is the greater the difference between the two readings.

Tables have been prepared by the United States Weather Bureau which with very little trouble will

interpret the readings of the two thermometer tubes.

As in all other things, accuracy of readings and accuracy of the thermometer tubes must be closely watched. To give an illustration of what an error of 2° Faht. may mean, either through careless reading of the thermometers or their inaccuracies, the following illustration may be of interest.



Hygrodeik

Suppose the "dry-bulb" thermometer reads at 70° Faht. and the "wet-bulb" thermometer at 58° Faht., tables show us that the humidity is 48%.

Now, suppose the "dry-bulb" thermometer reads at 70° Faht. and the "wet-bulb" thermometer is either in error or inaccurately read, so that instead of being 58° Faht. it reads at 56° Faht. This would indicate a

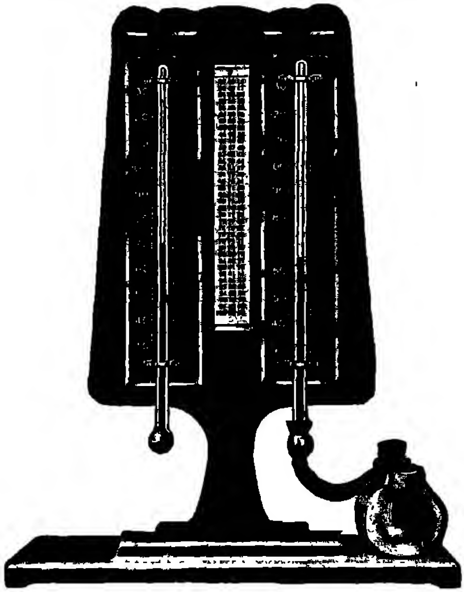
humidity by the tables of 40%, or a difference of 8%.

It is desirable to get, if possible, thermometers which have their scales and divisions etched upon their own tubes. Such thermometers are "standard" and will always give true indications of temperature.

One or two mechanical hygrometers are made which are worthy of investigation. Among the most popular forms are the "Hygrodeik" and the "Hygro-Autometer."

The Hygrodeik (page 89) has the thermometer tubes mounted at the extreme edges of a triangular chart. While on first examination the mass of scales and lines seem very complicated, they are really simplicity itself.

An index with adjustable pointer is designed to swing across the scales, and to take a reading it is necessary only to adjust the index to the same degree mark on the scale as is registered on the "wet" thermometer. Lines run from the "dry" thermometer downwards towards the "wet" one. Swing the index across the face of the chart until it meets the line coming from the degree mark of the "dry" thermometer. The relative humidity is then noted at the end of the index on the scale, marked, "Relative Humidity," which is the amount of moisture in the air expressed in percentage. There are lines which are etched from the top of the scale downwards to the right. If at the point of intersection of the index, the line is continued to the top, "absolute humidity" will be noted. This is the moisture expressed in weight—viz., grains per cubic foot of air, instead of in percentages. The bottom extremity of the line will give the "dew point," this being the temperature at which moisture will form in visible drops.



Hygro-Autometer

Let us take an example, with the "wet" thermometer at 52° Faht. and the "dry" thermometer at 60° Faht. Set the index at 52° Faht. on the "wet" side and swing it to the right until it intersects the line coming from 60° Faht. on the "dry" side. This gives us:

Relative Humidity—58% at the bottom of the chart.

Absolute Humidity. .3.4 grains per cubic foot, by following the line to the top of the chart.

Dew Point.........45° Faht., by following the line to the right-hand side of the chart.

The Hygro-Autometer (above) is arranged with a revolving paper scale suitably fitted between the "wet" and the "dry" tube, and rotated by thumb screws at the top of the frame. To read this simple instrument it is necessary only to deduct the reading of the "wet" from the

"dry" bulb and rotate the scales until the subtracted amount appears as the top figure. The first row of figures represent the "dry-bulb" reading and the figures by them the "relative humidity."

The illustration shows the scale with a difference of 5° in the readings of the thermometers and the scale in the center has "5" at the top. The "dry" thermometer reads 70° Faht. and by the side of the figure 70 on the scale is 77, which represents 77% of humidity.


The Sling Psychrometer.

This instrument is useful only for relative humidity purposes and is ideal for household use, besides providing a good-grade "air" thermometer.

The Sling Psychrometer is designed for the purpose of obtaining quick and more accurate results than are possible with the stationary wet and dry bulb instruments. The original design has been improved upon by doing away with the link connection between the thermometer back and the handle. The improved form lessens the liability to breakage in swinging and enables the user to more quickly obtain the readings than is possible on the less rigid, link handle form.

Sling psychrometers are considered standard instruments for all meteorological work and in the industries.

DEW AND FROST AND THE DEW POINT

DEW is the watery vapor of the air deposited on surfaces cooled by radiation. The quantity of dew depends on the degree of cold, and also on the conducting and radiating power of the surfaces upon which it collects.

Some articles will collect dew readily and so are called "good conductors." They include furs, cotton, silk, wool, vegetable substances, etc. Bad conductors include mould, sand, gravel, etc.

It seems that dew falls most upon objects which require its refreshing influence.

Dew rarely, if ever, collects on cloudy nights, for the clouds prevent the escape of the heat into space.

The "dew point" is indicated by the hygrometer, and in the evening it usually determines the lowest temperature of the night. By ascertaining the "dew point" the approach of a low temperature or a frost may be ascertained beforehand and be provided against.

When the "dew point" is indicated below the freezing point, frost will form instead of dew.

A profuse dew is a very sure sign of fine weather. The greater the difference between the "wet-bulb" and the "dry-bulb" thermometers, the greater will be the probability of the weather being fine, and vice versa.

As dew is not formed during a wind or when there is considerable cloud, it is an incidental indication of fine weather.

Hoar frost is really a sign of changeable weather.

COMPUTING THE DEW POINT

ON those instruments not designed to register the dew point in a semi-automatic manner, as the Hygrodeik, it is necessary to compute it with the help of tables.

The most simple method known to the writer is to use those tables known as "Greenwich Factors," which were originally laid out by Mr. James Glaisher, Fellow of the Royal Society, London.

To arrive at the dew-point reading it is necessary to carefully note the readings of the "wet" and "dry" tubes and subtract the lesser from the greater, the difference of which has to be multiplied by the factor corresponding to the "dry" reading given on the following page.

The product must then be subtracted from the dry-bulb reading and the result is the dew-point.

As an example, we will imagine the reading of the "wet" tube at 60° Faht. and the "dry" at 70° Faht.

Our sum becomes:

$$70°—60°=10.$$

The "factor" for 70 (which is the reading of the dry thermometer) is 1.77, therefore we multiply 1.77 by 10 and get 17.70. Now deduct this amount from the reading of the dry thermometer (70°—17.70) and we get 52.3° Faht., which is the temperature of the dew point.

When reading the tubes of a hygrometer it is as well to stand as far away as convenient, so that they remain unaffected by the warm breath and heat of the body of the observer.

RELATIVE HUMIDITY TABLES

Per Cent Fahrenheit Temperatures

Difference in Degrees Between Wet-and-Dry-Bulb Thermometers

Reading of dry bulb thermometer	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0
32	90	79	69	60	50	41	31	22	13	4							
33	90	80	71	61	52	42	33	24	16	7							
34	90	81	72	62	53	44	35	27	18	9	1						
35	91	82	73	64	55	46	37	29	20	12	4						
36	91	82	73	65	56	48	39	31	23	14	6						
37	91	83	74	66	58	49	41	33	25	17	9	1					
38	91	83	75	67	59	51	43	35	27	19	12	4					
39	92	84	76	68	60	52	44	37	29	21	14	7					
40	92	84	76	68	61	53	46	38	31	23	16	9	2				
41	92	84	77	69	62	54	47	40	33	26	18	11	5				
42	92	85	77	70	62	55	48	41	34	28	21	14	7				
43	92	85	78	70	63	56	49	43	36	29	23	16	9	3			
44	93	85	78	71	64	57	51	44	37	31	24	18	12	5			
45	93	86	79	71	65	58	52	45	39	33	26	20	14	8	2		
46	93	86	79	72	65	59	53	46	40	34	28	22	16	10	4		
47	93	86	79	73	66	60	54	47	41	35	29	23	17	12	6	1	
48	93	87	80	73	67	60	54	48	42	36	31	25	19	14	8	3	
49	93	87	80	74	67	61	55	49	43	37	32	26	21	15	10	5	
50	93	87	81	74	68	62	56	50	44	39	33	28	22	17	12	7	2
51	94	87	81	75	69	63	57	51	45	40	35	29	24	19	14	9	4
52	94	88	81	75	69	63	58	52	46	41	36	30	25	20	15	10	6
53	94	88	82	75	70	64	58	53	47	42	37	32	27	22	17	12	7
54	94	88	82	76	70	65	59	54	48	43	38	33	28	23	18	14	9
55	94	88	82	76	71	65	60	55	49	44	39	34	29	25	20	15	11
56	94	88	82	77	71	66	61	55	50	45	40	35	31	26	21	17	12
57	94	88	83	77	72	66	61	56	51	46	41	36	32	27	23	18	14
58	94	89	83	77	72	67	62	57	52	47	42	38	33	28	24	20	15
59	94	89	83	78	73	68	63	58	53	48	43	39	34	30	25	21	17

RELATIVE HUMIDITY TABLES

Continued

Reading of dry bulb thermometer	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0
60	94	89	84	78	73	68	63	58	53	49	44	40	35	31	27	22	18
61	94	89	84	79	74	68	64	59	54	50	45	40	36	32	28	24	20
62	94	89	84	79	74	69	64	60	55	50	46	41	37	33	29	25	21
63	95	90	84	79	74	70	65	60	56	51	47	42	38	34	30	26	22
64	95	90	85	79	75	70	66	61	56	52	48	43	39	35	31	27	23
65	95	90	85	80	75	70	66	62	57	53	48	44	40	36	32	28	25
66	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33	29	26
67	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34	30	27
68	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35	31	28
69	95	90	86	81	77	72	68	64	59	55	51	47	44	40	36	32	29
70	95	90	86	81	77	72	68	64	60	56	52	48	44	40	37	33	30
71	95	90	86	82	77	73	69	64	60	56	53	49	45	41	38	34	31
72	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39	35	32
73	95	91	86	82	78	73	69	65	61	58	54	50	46	43	40	36	33
74	95	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34
75	96	91	87	82	78	74	70	66	63	59	55	51	48	44	41	38	34
76	96	91	87	83	78	74	70	67	63	59	55	52	48	45	42	38	35
77	96	91	87	83	79	75	71	67	63	60	56	52	49	46	42	39	36
78	96	91	87	83	79	75	71	67	64	60	57	53	50	46	43	40	37
79	96	91	87	83	79	75	71	68	64	60	57	54	50	47	44	41	37
80	96	91	87	83	79	76	72	68	64	61	57	54	51	47	44	41	38
82	96	92	88	84	80	76	72	69	65	62	58	55	52	49	46	43	40
84	96	92	88	84	80	77	73	70	66	63	59	56	53	50	47	44	41
86	96	92	88	85	81	77	74	70	67	63	60	57	54	51	48	45	42
88	96	92	88	85	81	78	74	71	67	64	61	58	55	52	49	46	43
90	96	92	89	85	81	78	75	71	68	65	62	59	56	53	50	47	44
92	96	92	89	85	82	78	75	72	69	65	62	59	57	54	51	48	45
94	96	93	89	86	82	79	75	72	69	66	63	60	57	54	52	49	46
96	96	93	89	86	82	79	76	73	70	67	64	61	58	55	53	50	47
98	96	93	89	86	83	79	76	73	70	67	64	61	59	56	53	51	48
100	96	93	90	86	83	80	77	74	71	68	65	62	59	57	54	52	49

INSTRUCTIONS FOR THE PROPER CARE OF WET AND DRY TUBE HYGROMETERS

IN order to obtain accurate results from a hygrometer it is necessary to keep the instrument in a place where the air is in good circulation, and if used out of doors, exposed in such a way that air can circulate freely around the tubes. It must not be placed where the sun is apt to strike it, or in a place where it will be affected by radiated heat.

The muslin covering the wet tube must be kept very clean and must be replaced immediately it shows signs of discoloration, which always results when the water is charged with some mineral matter, such as lime, causing the pores of the wicking, or muslin, to become clogged, so that the water cannot properly reach the bulb and evaporate.

Directly the covering shows signs of hardening it must be replaced.

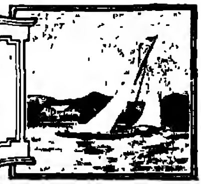
The necessity for this frequency of change will be obviated somewhat if distilled or clean rain-water be used, or even simple boiled water.

Accumulations of starch, dust, and dirt must be removed from any new wrapper before fitting it to the tube. This can be accomplished easily and quickly by boiling it in water for some time.

In very damp weather, and if the readings are taken outside, it is desirable to wipe off the "dry" bulb carefully with a soft cloth a few minutes before observation.

When refilling the receptacle with water a good deal of accumulated dust can be removed by pouring the water over the covering into the water cistern and drawing the thumb and first finger along it.

THE MOUNTAINS of CLOUDLAND AND RAINFALL

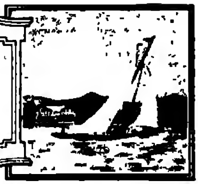


"Sometimes we see a cloud that's dragonish,
A vapour sometimes like a bear or lion,
A towered citadel, a pendant rock,
A forked mountain, a blue promontory
With trees upon 't that nod unto the world
And mock our eyes with air.
That which is now a horse, even with a thought
The rock dislimns and makes it indistinct
As water is in water."

Shakespeare.

Cumulo-Stratus Clouds

THE MOUNTAINS of CLOUDLAND AND RAINFALL



WONDERFUL scenery is found in Cloudland by those who study it—vast floating mountain masses and jagged peaks, alternating with hills and lakes dressed in the glowing sunlight.

Cloudland is not solid. It is nothing more, as a general rule, than masses of wet mist or fog, floating in the air at different heights, perpetually forming, increasing and decreasing, vanishing at times completely, reforming again—never remaining for any length of time in the same shape or the same place.

Clouds evaporate and condense again into the air. Every one we look upon is either growing larger or melting away. They never remain of the same size or form.

Due to the tremendous distance we are from some of them, they at times appear to retain their shape and remain in the same position, but as they are so far away we cannot detect any change in the short space of time we have them under observation. When they seem to be dormant and changeless it is only because of distance, or else because the whole sky is shut off by a gray pall of cloud which may grow or lessen without our being conscious of it.

Clouds, like fog and mist on the earth's surface, are commonly caused and dispersed by two currents of air meeting, one warmer than the other. If when these two currents meet and combine the air of the one is so cooled down that it cannot carry all its moisture, while the air of the cooler current is "saturated," or unable to take in more than it already has, a cloud is formed.

If a cloud is already there, it enlarges. If, however, these currents mix and the colder air gains warmth, the air has the power to take out a part, sometimes all, of any cloud it may come in contact with.

This is well illustrated by watching a teakettle boil. The steam particles pour out of the spout and are in ceaseless motion in the air until they finally disappear. If the air into which the steam pours is warm, the steam seems a good deal less in volume than it does when the air is cold. The reason is that as warm air can carry more moisture than cold air, it takes it up more rapidly.

When moisture laden air is carried along by a breeze and is poured up a mountain side, the surplus moisture is everlastingly being condensed into fog or cloud by the cold peak. Here the cloud ceases to grow, for the wind carries away the fog or cloud to be evaporated again into the atmosphere.

Clouds are divided into many forms, the twelve principal ones being Cirrus, Cirro-stratus, Cirro-cumulus, Alto-cumulus, Alto-stratus, Strato-cumulus, Nimbus, Cumulus, Cumulo-nimbus, Stratus and Fracto-Stratus.

The most common forms are the Cirrus, Stratus and Cumulus.

The Cirrus is known as the "Mare's Tail" cloud, the Stratus as the "Ground Fog" and the Cumulus as the "Wool Pack."

As perfectly pure specimens are rarely found in these three simple types, they are grouped in their mixtures and called "Compound Clouds." As a result of the International Committee's efforts, the names of these clouds have been arranged in an International Cloud Atlas, published in Sweden, and to quote from the booklet* issued by the U. S. Department of Agriculture, we find Stratus described as "a uniform layer

*Classification of Clouds, U. S. Dept. of Agriculture, Washington, D. C.

of cloud resembling a fog, but not resting on the ground." The complete absence of details of structure differentiates stratus from other compact cloud forms. When this stratus is torn by the wind or mountain summits into irregular fragments, they may be called "Fracto-stratus."

"Cumulus" is described as "thick clouds whose summits are domes with protuberances, but whose bases are flat." The true cumulus shows a sharp border above and below. It is often torn by strong winds and the detached parts present continual changes. It is known as the "Wool Pack" cloud, on account of its close resemblance to that material.

The combination of these clouds (Strato-cumulus) is described as "Large balls or rolls of dark cloud, which frequently cover the whole sky, especially in winter, and gives it at times an undulated appearance. The stratum of strato-cumulus is usually not very thick and blue sky often appears in breaks through it. It is distinguished from nimbus (the rain cloud) by the ball-like or rolled form and because it does not tend to bring rain."

It is often difficult, looking up from the floor of the Air-ocean, to decide with certainty on the class to which any cloud may belong. Practiced eyes are frequently at fault.

The cirrus clouds are usually at altitudes varying from 20,000 to 30,000 feet, cumulo- and strato-cirrus forms are found at intermediate altitudes, whilst cumulus, stratus and nimbus are low, many being below 2,500 feet. These levels are approximate only and vary with the latitude and the season of the year. It is interesting also to note their speed. At a height of about five miles the movement is practically three times as fast in summer and six times as fast in winter as air currents at the earth's surface. Usually, the greater the altitude the faster the movement.

From the foregoing it is easy to see that a cloud is pressed by a cold air-current out of a warmer one, and hangs suspended in countless millions of minute floating water drops. Occasionally, due to a change of wind or temperature, these drops are evaporated again into the air and as a consequence the cloud vanishes.

On the other hand, they may increase. More vapor is turned into mist or fog, making cloud, and it spreads over a wider extent. This causes the minute drops to crowd together and they run into one another and a larger drop is formed, which again joins others, making a still larger one. This can be illustrated by placing a sheet of cold glass against the spout of a boiling kettle and watching the condensation take place. A mist is formed first and then tiny drops appear. These unite with others and finally large drops fall to the ground.

Under ordinary conditions the air can hold these minute particles of moisture, but it cannot support for long the larger ones, and they fall to the ground as a shower of rain. Air that is in circulation can support a heavier weight than air which is still. A gale can keep rain particles in the upper regions, which could not be held up by a gentle breeze. This fact probably explains the difference in the size of rain drops. Quite often strong winds are blowing in the upper regions, while here below we may have calm. This is explained by the speed of clouds at high altitudes.

Briefly, rain is caused by the chilling of the air. This chilling takes place in many ways—either by its rising into higher and colder levels, through its contact with a colder surface, or from its meeting with a colder current of air. Rain often arises through the rushing of warm lowland air up a mountain side and that is why some of the heaviest rains occur on or by mountains situated near the sea.

Air travelling over the ocean becomes saturated

with vapor which can be carried while the air current is warm. If it suddenly comes against a mountain range it loses part of its heat in rushing upwards. It becomes colder and cannot retain all its moisture. Floating clouds of mist are formed and torrents of rain result.

The amount of rain which falls varies considerably, a good average for a year being 30 to 40 inches. In ordinary climates it seldom exceeds one inch in twenty-four hours, but in some places this is increased to an extraordinary amount.

The Western Ghats of India, along the Bombay Coast, show the influence of mountains, the heaviest rainfall occurring near the N. E. corner of the Bay of Bengal in the Khasia Hills, which offer an abrupt wall about 4,000 feet high. Chirapunji at the edge of these hills has a rainfall averaging 500 inches a year, half of which falls in two months. Mohableshwar receives about 250 inches, while the table land of Deccan suffers from drought.

To give some idea of the great damage caused through these tremendous downpours, it is interesting to note the following report on damage caused by rain at Hyderabad, India, September, 1908.

> "* * A resolution to the effect that the meeting offered its deep sympathy with his Highness the Nizam of Hyderabad and his people, and that a committee be authorized to collect subscriptions by appeal to the public, and transmit the money to the distressed persons. The flood took place in September, when there was a tidal wave on the Moosi River. After three days' heavy rain, suddenly a wave 12 ft. high rushed down the river, overflowed the banks, and spread death and destruction for half a mile on each side. The water rose to a height of 60 feet, and the three bridges crossing the river, which had been built

with provision for a rise of 40 ft. of water, were practically demolished. About one-fifth of the city was wrecked, 15,000 human habitations were destroyed and 100,000 men, women and children were rendered homeless."

On June 12, 1876, the heaviest rain on record fell. It registered at Chirapunji over 40 inches in twenty-four hours.

The eastern coast of Australia has an annual rainfall of 160 inches, while on the south it rarely exceeds 25 inches. South African rainfall varies from 22 to 41 inches, the east coast having the heaviest and most regular, due to the S. E. winds which blow from November to February. Colombo, Ceylon, registers 80 inches on the average, but at Sembawatta in the mountains, 15 miles south of Kandy (Ceylon) 231.3 inches fell in 1909—a record for this particular district. Japan (taking the average of the nine principal meteorological stations) has a trifle over 60 inches yearly. From these few illustrations it is easy to see how the rainfall varies over our globe.

By the term, "annual rainfall, so many inches," is meant the depth of water that would be obtained if all the rain which falls there in a year were collected into one horizontal sheet, and none were lost by evaporation or absorbtion into the soil. The term "one inch of rain" means that if all the rain falling over a given area were collected and spread out uniformly it would form a layer "one inch in depth."

When we get temperatures below a certain point we get snow instead of rain. Snow is not frozen rain, as popularly supposed. It falls directly as snow from snow clouds. It is generally believed that clouds at a great height are not formed of fog or mist, but of tiny interlaced ice-needles. They are, in short, frozen.

Halos and mock suns bring us to this conclusion, for they are seen (by refraction) always through high

level clouds and never through low level ones. They could not possibly be caused by the passing of light through mist. If at certain low temperatures on earth we get hoar-frost instead of dew, and snow in place of rain, why should we not get frozen clouds in place of mist-clouds in Cloudland?

Clouds

Soft looking or delicate clouds foretell fine weather, with moderate or high breezes.

Hard-edged clouds, wind.

A dark, gloomy, blue sky, windy but light.

A bright blue sky indicates fine weather.

A bright yellow sky at sunset presages wind; pale yellow, wet.

By the prevalence and kind of red or yellow, or other tints, the coming weather may be foretold.

Generally the softer look, the less wind (perhaps more rain) may be expected, and the harder, more "greasy," rolled, tufted, or ragged, the stronger the coming wind will prove.

Small, inky-looking clouds foretell rain.

Light scud clouds driving across heavy masses show wind and rain, but if alone, may indicate wind only.

High upper clouds crossing the sun, moon or stars, in a direction different from that of the lower clouds, or the wind field below, foretell a change of wind toward that direction.

The Sky

Whether clear or cloudy, a rosy sky at sunset presages fine weather.

A sickly-looking, greenish hue, wind and rain.

A dark (or Indian) red, rain.

A red sky in the morning, considerable wind or rain.

A gray sky in the morning, fine weather.

A high dawn, look out for wind.

A "high dawn" is when the first indications of day-light are seen above a bank of clouds.

A "low dawn" is when the day breaks on or near the horizon, the first streaks of light being very low down.

Prognostications

After fine weather, the first signs in the sky of a coming change are usually light streaks, curls, wisps, or mottled patches of white, distant clouds, which increase and are followed by an overcasting of murky vapor that grows into cloudiness. This appearance more or less watery, as wind or rain will prevail, is an infallible sign.

Usually the higher and more distant such clouds seem to be the more gradual but general the coming change of weather will prove.

Light, delicate, quiet tints of color, with soft, undefined form of clouds, indicate and accompany fine weather, but unusual or gaudy hues, with hard, definitely outlined clouds, foretell rain, and probably strong wind.

Misty clouds, forming or hanging on heights, show wind and rain coming, if they remain, increase or descend; if they rise or disperse, the weather will improve or become fine.

Cirro-Cumulus

Cumulo-Nimbus

Cloud Forms *Courtesy U. S. Weather Bureau*

VARIETIES AND SPEEDS OF CLOUDS

(Archibald)

Height	*Name*	*Description*
Sea level up to 3,000 ft.	Stratus	Elevated fog, so-called.
4,500 to 6,000 ft. 4,500 to 24,000 ft.	Cumulus Cumulo-nimbus	Rounded heap tower-like clouds with round tops and flat bases.
6,400 ft.	Strato-cumulus	Rolls of dark cloud.
6,400 ft.	Nimbus	Masses of dark formless cloud.
10,000 to 21,000 ft.	Cirro-cumulus	Fleecy cloud, mackerel sky.
27,000 ft. (average)	Cirro-stratus	Fine whitish veil, giving halos around sun and moon.
27,000 ft. (average)	Cirrus	Isolated feathery white clouds.

Cloud level	*Height in feet*	*Average speed in miles per hour*
Stratus	1,676	19
Cumulus	5,326	24
Alto-cumulus	12,724	34
Cirro-cumulus	21,888	71
Cirrus	29,317	78

RAIN GAUGES AND THE MEASUREMENT OF RAINFALL

THE first use of the rain gauge has been credited to Benedetto Castelli, an Italian contemporary of the great philosopher Galileo, but older records of weather show the use of rain gauges in the 15th century.

In the historical records of Korea, rain gauges are mentioned during the 24th year of the reign of King Sejo (A. D. 1442), who "ordered constructed a bronze instrument to measure the rainfall." It consisted of a vase resting on a stone base and was placed near the observatory of Taiko. Reports of the depth of rainfall were then sent to the King.

Since this time improvements have been made in rain gauges, as in all things. There are many forms in common use, from the simple funnel which terminates in a bottle to the expensive and more accurate rain gauges worked electrically.

All rain gauges are patterned more or less after the one designed by Luke Howard, the eminent Quaker and meteorologist, whose careful study of cloud phenomena in 1783 led to a classification and nomenclature for these, now universally adopted.

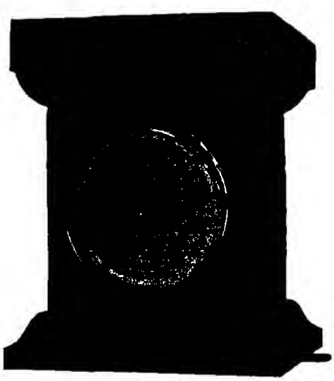
A funnel of copper, or some other non-rusting metal whose upper diameter is five inches and whose lower end terminates in a collecting bottle of some kind, will serve as an elementary rain gauge. This whole can be enclosed in a copper vessel of cylindrical design for the sake of protection and to lessen the liability of errors from evaporation. Rain gauges are made with funnels of diameters to ten inches, but those almost universally used measure either five or eight inches. According to Scott, results from experiments made on gauges 3 to 24 inches in diameter show errors hardly exceeding one per cent.

The Standard U. S. Weather Bureau rain gauge con-

sists of a cylindrical galvanized iron case about 8 inches in diameter and 25 inches high provided with a funnel receiver with a sharp bevelled rim at the top.

The gauge designed by James Glaisher, F. R. S., and known throughout the world, consists of a copper case, 14½ inches high, having a receiver 8 inches in diameter. A small leaden curved tube which holds water, thereby preventing evaporation, is fitted to the end of the funnel.

The fall is received into a copper cup the contents of which are poured into a graduated measuring glass divided to one hundredth of an inch.



Wherever possible, gauges of registering type should be used. These are mostly operated on the tipping bucket principle.

Two buckets adjustably attached to an arm will, when laden with water, tilt. This causes a movement of a train of wheels, the registration being noted on the dial.

As they tilt and register at each one hundredth of an inch and throw away their water, no errors from evaporation or careless reading can occur and the reading can be taken at any time and the hands set back to zero. As the dial registers upwards to twelve inches, records by the week or month can readily be taken.

The "Electrical Tipping Bucket" rain gauge has a small bucket below the funnel, which "tips" after having received 1-100th of an inch of rain. The amount of rainfall is measured by the number of "tips," which is electrically recorded any reasonable distance away.

Then there is the "Weighing Gauge," an instrument devised for weighing the amount of rain or snow fall. This is probably one of the most accurate styles, as no loss occurs from evaporation or melting if snow is measured.

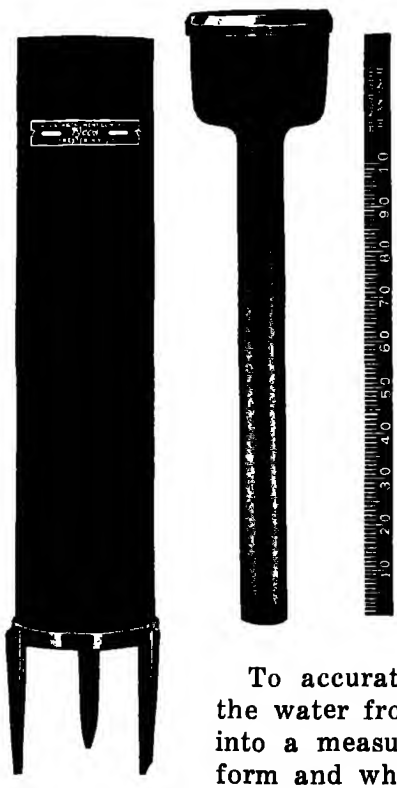
The exposure of a gauge is of great importance. It should be in an open lot, as far from trees and buildings as their height. Best results are obtained by placing it about 12 to 15 inches above the ground, dependent on the style of the instrument. Low bushes or walls that will break the force of the wind in the vicinity of the gauge are beneficial, if at a distance not less than the height of the object. The wind is the most disturbing element, for it causes eddies at the top or mouth of the gauge. If a fence about three feet high is set at a distance of three feet from the gauge it will offer all the protection necessary.

When snow has to be measured in place of rain it is usual to select some spot where the snow shows no signs of having drifted and invert the rain gauge, pressing it downwards, until the earth is reached. By turning it gently it will be found possible to lift up the snow in the circumference of the rain gauge. This can be melted by leaving in a warm room, or by adding a given amount of warm water to reduce the snow to

liquid. If the last method is adopted it will be necessary to remove the amount of water used to reduce it to liquid before attempting to measure the rest.

As snowfall is rather uncertain it is well to take three or four samples and obtain an average, rather than to accept any one result.

The funnel terminates into a brass cylinder which has just 1-10th the area of the outer can. The water collecting in the upper funnel drips into the brass cylinder and the depth of water in this is determined by inserting a measuring rod and noting the height to which it is wetted.



The official Meteorological Office rain gauge (Great Britain) consists of a copper can and removable funnel combined, 18½ inches high, fitted with a sharp bevelled brass collar at the top. The funnel terminates in a brass tube about 5½ inches long, which is introduced into a bottle designed to collect the rain. This bottle is divided to three inches in half inches, so a rapid estimate can be taken if desired.

To accurately determine the fall, the water from this bottle is poured into a measuring glass of improved form and which is divided into hun-

dredths of an inch. The bottom is designed as a cone, the division being sub-divided to two one hundredths (.005) of an inch.

The number of inches of snow which correspond to an inch of water is not constant. It varies from 6 to 25, but a good average is 10.

To give an idea of the amount of water that falls on an acre of ground, the following will be of interest.

0.01	in.	of	rain	equals	62,726	Cu.	in	or	1.1	tons
0.05	"	"	"	"	313,632	"	"	"	5.6	"
0.10	"	"	"	"	627,264	"	"	"	11.3	"
1.00	"	"	"	"	6,272,640	"	"	"	113.0	"
2.00	"	"	"	"	12,545,280	"	"	"	226.0	"
5.00	"	"	"	"	31,363,200	"	"	"	565.0	"

THE COMPASS THE SIGNPOST OF THE WORLD

HISTORY

LIKE many other things, the compass originated in China, where it was first used on land and later as a guide to mariners.

The name of its inventor is lost to history, but we find mention of it in a satire by Guyot de Provins, a French poet of the twelfth century, and one of the Crusaders.

The Venetian, Marco Polo, is supposed to have introduced it into Europe in about 1260 A. D. His work was furthered by another Italian, Flavio Gioja, a Neapolitan navigator, to whom belongs the credit of the suspension of the needle in 1302 A. D. Legend also has it that the Swedes were familiar with the compass in the time of King Jarl Birger, 1250 A. D.

The two great explorers, Christopher Columbus and Sebastian Cabot, discovered the variation of the compass, the one in the year 1492, the same year as the discovery of America, and the other in 1540. William Barlow, an English divine and philosopher, invented the compass box and hanging compass used by navigators, in 1608.

The exact location of the North Magnetic pole was first determined by the famous English polar explorer, James Clark Ross, in 1831. It was located in about Longitude 96° 40′ W. and Latitude 70° 10′ N. near Cape Adelaide Regina, Boothia.

In order to accurately find direction, some appliance must be used which will properly determine it.

The ancients used the Sun and Stars, but since the advent of the compass such ideas have almost com-

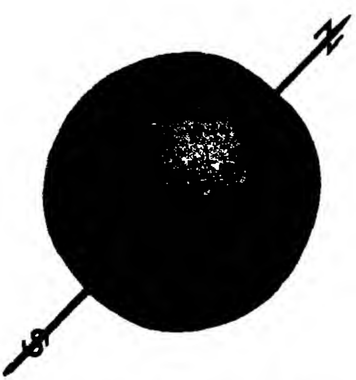
pletely disappeared, although one can quite often find a person who will determine approximate North and South with his watch when the sun is shining.

In order to give direction which will never mislead and which will serve a person in any part of the world, it is necessary to have a FIXED point upon which all persons will agree, and one by which every person will know in what direction to go when it is mentioned. If an order could be given for everyone in the world to look North at a certain time, all people would be facing the same direction, with the South at their backs.

We learned at school that our world is shaped somewhat "like an orange, but flattened slightly at the top and bottom." If we take a knitting needle and run it through the centre of an orange we have a very good example of the earth and the North and South poles to which compasses point.

If we now draw a series of lines from one end of the needle over the surface of the orange to the other end, all of these lines will point to the North and South position.

It matters not if the position be at the bottom, the top, or the sides, the line always points in the same direction.



The Earth is Like an Orange with a Knitting Needle Pushed Through it.

Whatever part of the world we happen to be in, North and South are in the same direction.

Also it is true that East and West are in a fixed direction, for, facing the North, the East is always on our right hand and the West is always on our left hand.

North, East, South and West are the four chief

points on the compass and are called the "Cardinal Points." The word "cardinal" is taken from the Latin "cardo," a hinge. The other points are supposed to hinge or turn on the four principal or cardinal points.

There are twenty-eight other divisions of the compass, making thirty-two in all, which are generally known as the "points" of the compass.

Beginning from the North they are placed as follows:

North ....N.
North by East......................N. b. E.
North North East..................N. N. E.
North East by North...............N. E. b. N.
North East.........................N. E.
North East by East................N. E. b. E.
East North East....................E. N. E.
East by North......................E. b. N.
East ....E.
East by South......................E. b. S.
East South East....................E. S. E.
South East by East................S. E. b. E.
South East.........................S. E.
South East by South...............S. E. b. S.
South South East..................S. S. E.
South by East......................S. b. E.
South ....S.
South by West......................S. b. W.
South South West..................S. S. W.
South West by South...............S. W. b. S.
South West.........................S. W.
South West by West................S. W. b. W.
West South West...................W. S. W.
West by South......................W. b. S.
West ....W.
West by North......................W. b. N
West North West...................W. N. W.

North West by West................	N. W. b. W.
North West........................	N. W.
North West by North...............	N. W. b. N.
North North West..................	N. N. W.
North by West.....................	N. b. W.

The dials of compasses are marked in divisions. There are, as we know, 360 degrees to a circle and, as there are 32 points to the compass, the value of the angle between each point is 11¼ degrees.

Of course, it is a simple matter to divide a compass dial into more than 32 points, but this number has been found sufficient for ordinary use.

In directing a person it is far more accurate and satisfactory to say turn North, South, East or West than "straight on," "to the right," or "to the left."

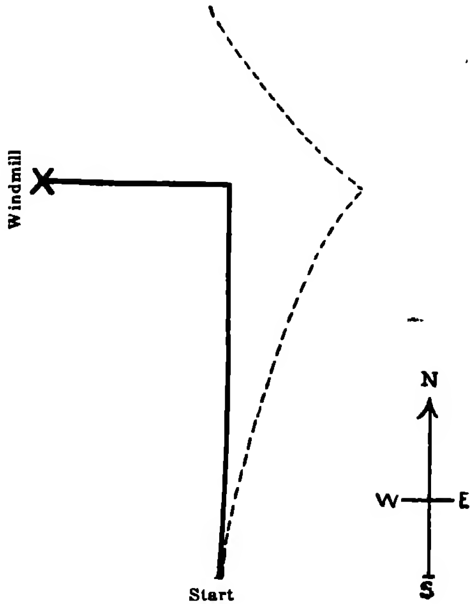
As it is impossible to walk in straight lines, a person may bear to either the right or left in walking, so it is easy to see that direction would mean nothing at all.

For an example, let us imagine we directed a man over some fields and for general direction told him to "walk straight on for a mile and then turn sharp to the left, when the windmill would be found about half a mile away."

The black line in the example would be the direction as given, but the dotted line might quite easily be the route taken by the directed person. Needless to say, he would not find the windmill, and he would have no idea in which direction to look for it.

If the person who directed him had told him to travel in a compass direction—say North for a mile and then walk half a mile to the West—he could not help but arrive at the place, for a compass always points in the same direction.

To return safely he would walk half a mile to the East and a mile to the South.



Magnetism is a power which surrounds the whole earth and which attracts magnets of iron, and steel bodies containing this property.

Back in the times of the early Chinese a black ore was found to possess "Magnetism." The name "Magnet" and that of its force, "Magnetism," were derived from the ancient city of "Magnesia" in Asia Minor, near which place ore possessing this peculiar property was first discovered.

The scientific name for this ore is "magnetite," but the name of "lodestone" or "leading" stone has also been given it because, since it always points to the same direction when carefully suspended, it was used in the navigating of ships.

Some of this ore in its natural condition does not always possess this peculiar magnetic property, but can easily be made to do so.

If we take a knitting needle, iron bolt, steel pin, or anything made of iron or steel, and dip it in iron filings, we find on withdrawing it that none of the filings have adhered to it. Now if we take the same knitting needle, iron bolt, steel pin or anything made of iron and steel, lay it on a table and stroke it from end to end in ONE direction with ONE end of a lodestone and then dip it in the filings, we find on withdrawing it that the filings have adhered to it, and much more thickly at the end than at any other place.

If we shake these filings off and suspend the needle on a silk thread so it can move freely in a horizontal position we will be in possession of a magnet and a needle which will point to the North and South as long as it can retain the magnetism which has been induced in it from the lodestone.

This is called an artificial magnet and the needles of high grade compasses are induced with magnetism in the same manner, but of course many refinements are added in order to make the magnetism strong and permanent in the needle.

A piece of magnetized steel or iron possesses what are called "poles"—a north pole and a south pole. One half of the needle contains northern magnetism and one half contains southern magnetism. If we break this into halves we have two complete magnets, each containing a north and south pole, and not one piece containing northern magnetism and another southern magnetism, as would be popularly supposed. Break these pieces again and again into a hundred pieces, if you please, and it will be seen that each piece is a complete magnet in itself, each containing a north and south pole, as in the larger and original magnet.

If we dip any of the pieces into iron filings it will be seen that the two ends are practically covered, while no filings adhere to the centre. The centre, or point

of joining of the poles, is called the magnetic equator or neutral line.

Now we find that a needle properly magnetized or suspended will point north and south, and if we attempt to try and make it point in any other position it will swing back and come to rest in its original position—viz., north and south.

We also find that if we bring the "north" end of another needle to that end of our needle pointing north, it will be seen to turn away and the south end of it will attract itself to the north end of the one we are holding.

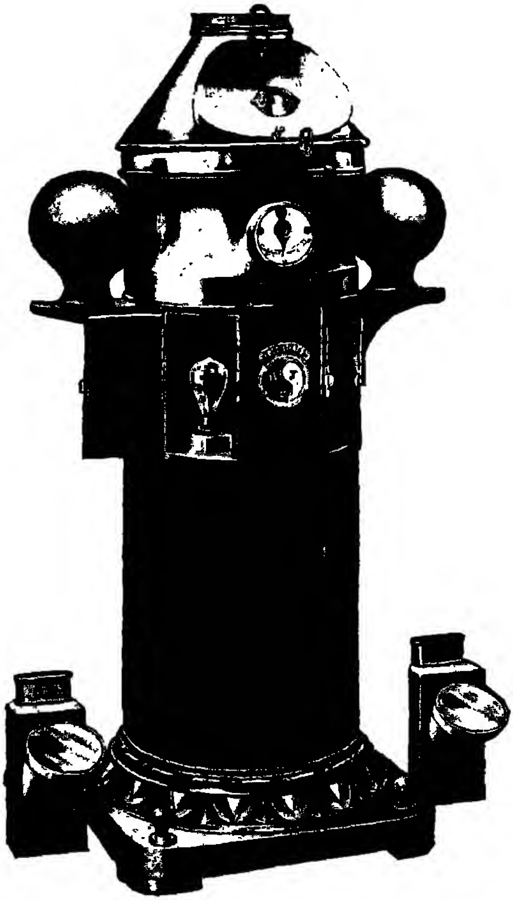
If we offer the north end of the suspended needle the south end of the one we are holding, it will attract itself to it, which goes to prove that like poles repel one another and unlike poles attract one another.

In reality the end of every compass needle that points in a Northerly direction is the south end, or the end containing southern magnetism, for the northern magnetism of the earth attracts the opposite, or southern, magnetism of the needle, but as that end POINTS to the north it is always called the North end.

If we take a knitting needle and before magnetising it balance it by a silk thread in a horizontal position we will find that after stroking it with the lodestone, as explained before, and suspending it, that the end which points to the North pole has a decided inclination to dip.

Should this needle be taken to the equator and suspended in the same way it will be found that the needle lies in a perfectly horizontal plane. Take it into the Southern Hemisphere and the south end of the needle will dip, and will increase its dip the nearer we travel toward the pole.

A simple way to illustrate this is to take a knitting

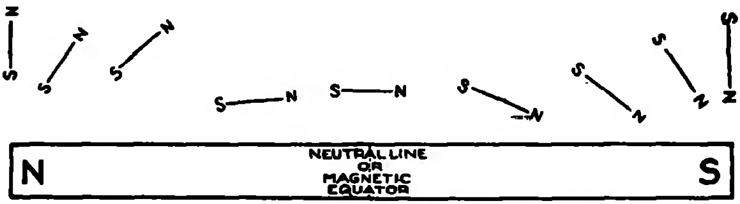


Lord Kelvin's Standard Compass as used at sea

or ordinary needle and suspend it on a silk thread very carefully, so that it assumes a horizontal position. Now magnetize the needle as explained, and on holding it up it will be found that not only will it point North and South, but will dip downwards towards the north.

By getting a long straight magnet (called a "bar magnet"), and holding the suspended needle over the

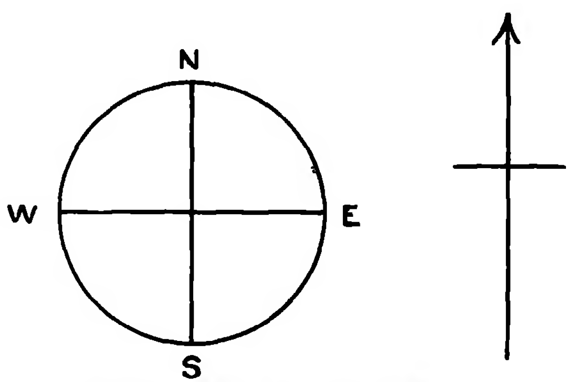
centre of it, it will assume a horizontal position again. The nearer it is held to the north end, the greater will be the dip in that direction, and the nearer it is held to the south end, the greater will be the dip toward the south. At the extreme end, or pole, it will be seen to be in a vertical position.



An Idea of Compass "Dip" in Different Localities

This illustrates the magnetic force surrounding our planet. At the equator a magnetic needle is parallel to the axis of the earth. At the poles it dips, and its dip in any other part of the Northern or Southern hemisphere is dependent on its position in the hemisphere.

From the various illustrations it will be seen that it is possible to produce a mechanical appliance of steel which will, if properly and sensitively made, always point in one direction, viz., north and south.

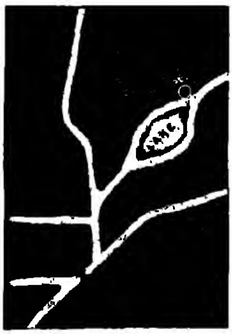


Familiar Direction Signs Found on Maps

These points are acknowledged throughout the world, and directions of value are reckoned as North or South, East or West of a certain place.

Countries, places and rivers are drawn in miniature on maps. They are absolutely to scale, but on each map, if it be of any value, an arrow appears which indicates the position of all places, although it is usually taken for granted that the top of the map is North.

A person attempting to find his way by a map without a compass would be as well off as a steamer with-



A

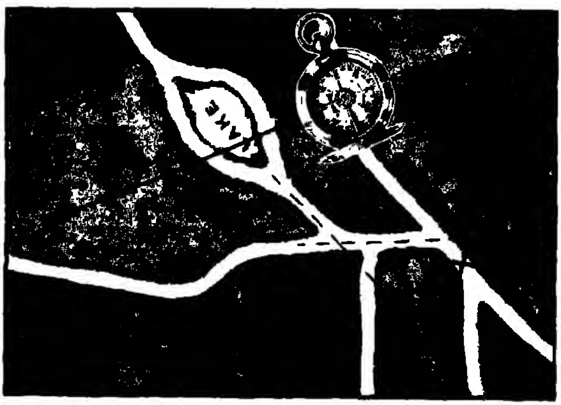
C

B

out a propeller. It would be almost impossible for him to put the map in front of him, so that it would be a reproduction of the country ahead of him, unless he knew positively and absolutely in which direction North was.

A lake might be located a few miles away, but it would be impossible to find it unless we knew the direction it was in. We could walk forward or backward, to the right or left, but such attempts would be aimless, unless we followed in the right direction, which can only be determined by accurately locating North and South.

How would you determine which way to go if you had a map as on page 130? It would be useless to try unless you had a compass to find out WHERE NORTH WAS. The example "D" map explains it.



D

First place your compass on the map and find your position. Starting at X you walk in direction N. E. b. E. until you come to road running a little N. E. of N., follow this up until you strike road running N. E. b. E., follow this and walk around N. side of lake and you arrive at O.

It is simple to see that by placing the compass on a

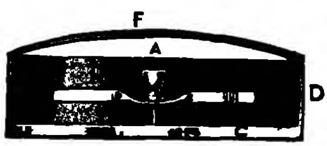
map and arranging the direction of the map in accordance with the readings of the compass, all the roads, etc., ahead and behind you are placed in their correct position on the map, if the compass is a true one.

Compasses are made in a variety of styles and patterns. There are many freak designs, which enables manufacturers to sell fancy but unserviceable articles to the unsuspecting public.

A compass needle in every instance should be jewelled. A hole is usually drilled in the centre of the needle, into which is inserted a brass cap, the top of which is fitted with a jewel of some description.

This needle operates upon a finely ground, sharpened, and tempered steel point—a point which must not become easily dull, nor one that will snap off at the top, if the compass is illtreated.

The point is securely fixed to a box of some design, having a dial in its base, and which is fitted into a case of either open or hunter model. A crystal glass covers the top, to protect it from damage or dust.



A—Brass cap set with jewel
B—Steel magnetic needle
C—Dial with cardinal points
D—Case into which compass is fitted
E—Point upon which "A B" operates
F—Covering crystal

In all good compasses a small contrivance called a "stop" is fitted. This is for the purpose of mechanically lifting the needle and jewel off the point, for protection when not in use.

In order to determine which end of a pocket compass needle points in a northerly direction it is usual to mark it in some way. Some polished steel needles have their north-seeking ends blued, some have a wire

wrapped round them, and others have a small pin inserted through them. One method is as good as another, the difference usually being due to the pattern of the needle.

Blued flat needle

Bar pattern needle with wire wound at "N" end

Flat half blued needles are usually found in the cheaper forms of compasses. They are very satisfactory, light and sensitive, but are not quite so good as those of bar design. Bar needles when properly made, adjusted, magnetized and hardened are the most desirable pattern. All high grade, needle compasses are fitted with magnets of this style.

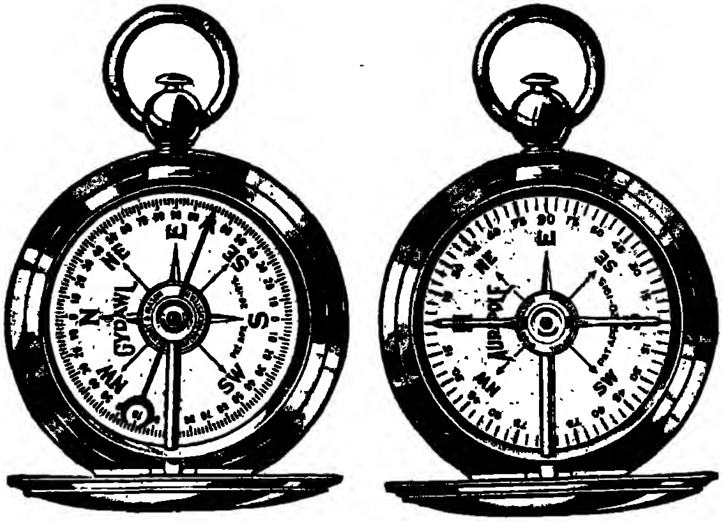
"Folded" needles are not to be desired. A great many imported compasses of "bar needle pattern" are fitted with needles stamped and folded into the shape of a bar needle and soldered together at their under edges. These are "fake" compasses, very undesirable and likely to become grossly inaccurate.

Flat and bar pattern needles are used with a fixed dial divided into degrees and lettered with the principal points of the compass. This dial is permanently fitted to the base of the case.

Some dials are of card, some of silvered metal and some of aluminum. The two latter styles are to be preferred, as they will not only retain their color, but will not buckle when damp. A buckled dial invariably interferes with the action of the needle, and usually needs replacing frequently.

A great many compasses are sold in which the dial is made to float by fitting it to the needle. Naturally in compasses of this kind the dial must be of very light material and aluminum is nearly always used on this account.

With floating dial compasses the needle is enlarged



Illustrating Compasses with blued flat and bar needles in hunter cases with metal fixed dials

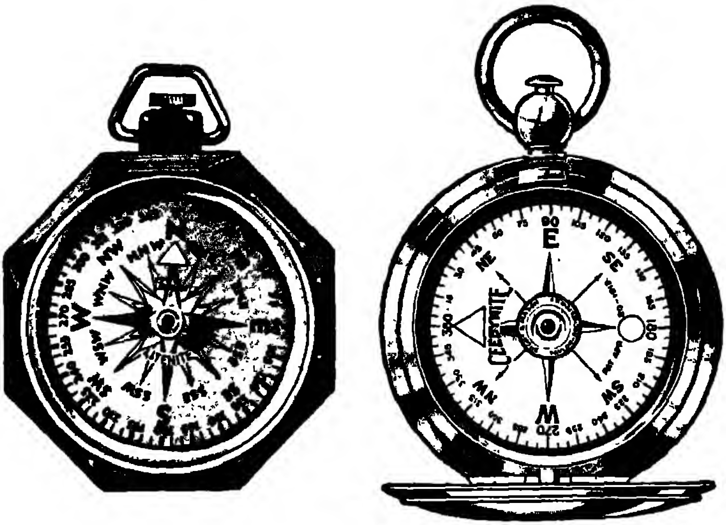
and is of thicker metal than those of "flat" or "bar" type.

There are many advantages in the "floating dial" compass which are not appreciated.

In the first place, all directions are correctly given when the dial comes to rest, for the dial is fitted to float with the needle. It is an easy matter to move round with one of these compasses in your hand without at any time disarranging its setting.

This is not true of those of "needle" pattern, for, as the dial is fitted to the bottom of the case, the case has to be turned after the needle has come to rest in a northern and southern direction, until the N seeking end of the needle is directly above the "N" mark on the dial.

In addition, some floating dial compasses have their N. and S. ends treated with a radio-active material which enables them to be seen at night. An arrow head is painted to represent the "N" end, and a small dot in a circle represents the "S" end.



Different styles of Compasses having radio-active material on their N. and S. ends

This material must not be confused with the old luminous paint so often used on signs, clocks, etc.

Luminous paint had to be exposed to sun light for the purpose of absorption and after dark it would remain luminous for a few hours.

Radio-active compound need not be exposed to the light and will remain active indefinitely.

Do not condemn a compass treated in this manner if the points cannot be seen immediately. Remember they are for use at night and cannot be seen when going from daylight into a darkened room.

The eyes are in a neutral state at night and a compass should be tested in the manner in which it is intended to be used.

If it is essential they be "tested" in the daytime, go into a perfectly dark room and remain there for about half an hour and allow the eyes to become neutral. The glow from the N. and S. points will after some time appear to shine and then disappear. Presently

they will become visible again and remain so, becoming brighter the longer one stays in the dark.

The prismatic compass is used for surveying, more especially for military purposes. It consists of a brass box about 2 inches in diameter. Upon the pivot is balanced the magnetic needle, to the top of which is fixed a pearl dial correctly divided into degrees.

As horizontal angles can be observed with great rapidity, it is a very valuable instrument to the military surveyor, who can make observations (holding the compass in his hands) with all the accuracy necessary for an observation or sketch; to obtain absolute accuracy the use of a tripod stand is necessary.

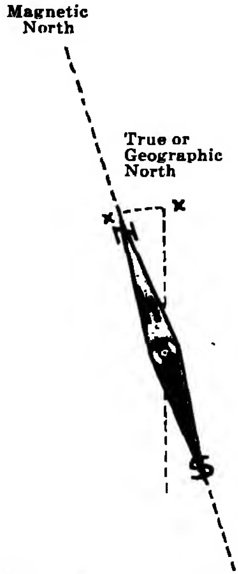
In conclusion, it is well to bear in mind the following requirements of a pocket compass:—

(a) Sensitiveness of action.
(b) Accuracy of magnetic needle.
(c) Jewelled centre to needle.
(d) Stop arrangement to check action.
(e) Construction capable of repair when anything goes wrong with it.
(f) Heavy tempered steel point for needle to operate upon.

THE DECLINATION OF THE COMPASS

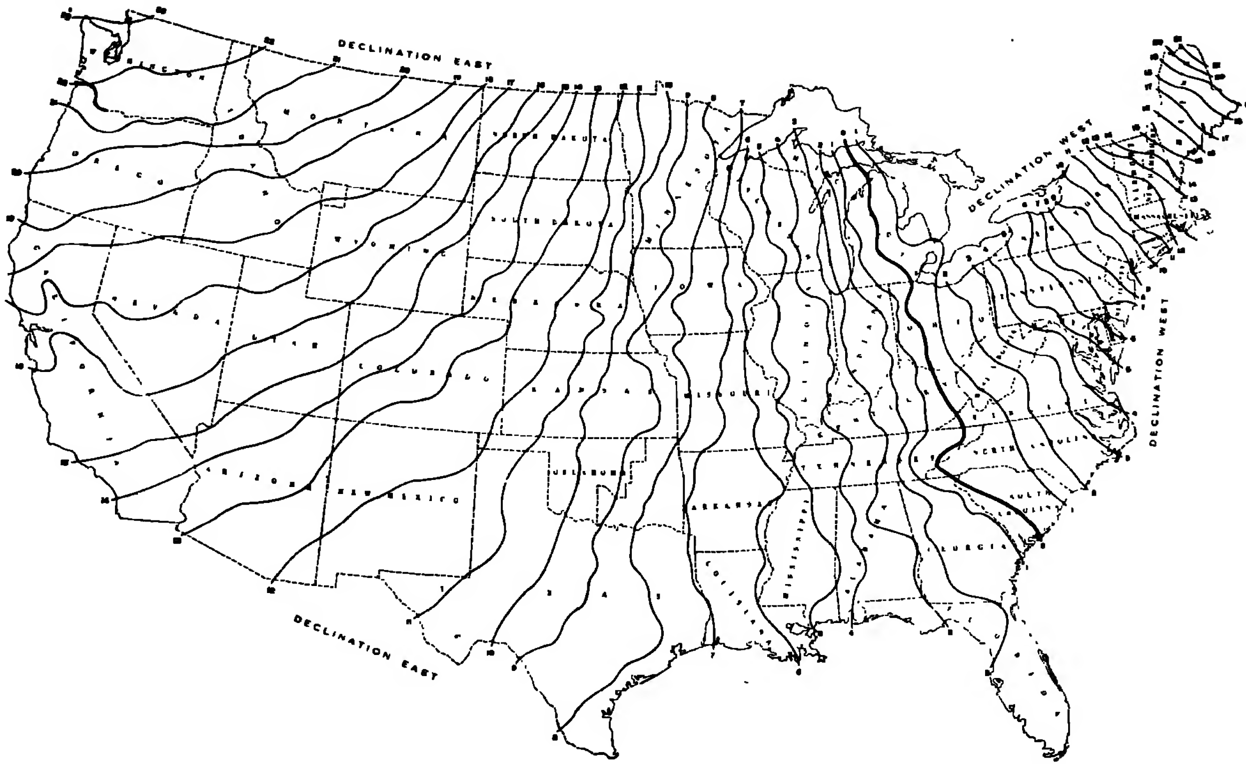
As the Magnetic North pole is not located at the same point as the Geographic North pole, and as all maps are drawn to a Geographic North instead of a Magnetic North, there is necessarily a correction to the readings of compasses used in places which are not in a true North and South position.

The angle between the two readings is called the "Magnetic Declination," or "Variation of the Compass," and should be applied to the reading of the compass when very exact readings are required.



X X equals angle of declination

In the United States the compass is correct in a line starting about 35 miles west of White Fish Point, Mich., thence passing south to a point 9 miles west of Lansing, Mich., 9 miles west of Ann Arbor, Mich., 9 miles west of Toledo, Ohio, 9 miles east of Lima, Ohio, 30 miles west of Columbus, Ohio, 58 miles east of Cincinnati, Ohio, 93 miles east of Lexington, Ky., 25 miles west of



DECLINATION EAST
DECLINATION WEST
DECLINATION EAST
DECLINATION WEST

Abingdon, Va., 36 miles east of Knoxville, Tenn., 12 miles east of Robbinsville, North Carolina, 25 miles west of Greenville, South Carolina, 17 miles west of Columbia, South Carolina, directly through Orangeburg, South Carolina, and then to the North Atlantic Ocean, 20 miles south west of Charleston, South Carolina.

In Astoria, Oregon, the declination is 22° East and in the extreme northern part of Maine it is 21° West.